TRMM-490-022
REVISION : B

TROPICAL RAINFALL MEASURING MISSION (TRMM) SPACECRAFT

TO

LIGHTNING IMAGING SENSOR (LIS) INSTRUMENT

INTERFACE CONTROL DOCUMENT

May 24, 1995

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

1. INITIATED BY: F. Grena	ORG: MDA/490	PHONE:	
CONFIGURATION CHANGE REQUEST TRMM GSFC	2. CCR NO: WV-0477	3. REV:	PAGE 1 OF 2
	4. CLASSIFICATION ■ CLASS I ☐ CLASS II	5. PRIORITY ■ ROUTINE ☐ URGENT ☐ EMERGENCY	
	6. DATE ISSUED: 6/30/95	7. DATE CLOSED: 7/19/95	

8. CCR TITLE: Waiver for Mechanical Relays in the LIS ICD

9. DOCUMENTS AND CONFIGURATION ITEMS AFFECTED:

TRMM-490-022: LIS ICD; Paragraph 7.3.3.3

10. DESCRIPTION OF CHANGE:

This is to request a waiver from paragraph 7.3.3.3 of the LIS ICD; TRMM-490-022; page 7-12b ; sentences as follows: "All secondary LIS instrument switching functions shall be accomplished within the LIS instrument and shall be acomplished without use of mechanical relays unless approved by the TRMM Project. All heater control should be handled with series redundant thermostats."

The LIS instrument requests a waiver in regard to the use of mechanical relays and the TRMM Project's approval for their use in the LIS instrument.

11. REASON FOR CHANGE:

During normal operation, the LIS instrument employs a temperature controlled lens filter assembly which requires the temperature controlled to 1.5 °C. This is accomplished through the use of temperature sensors and a lens filter heater circuit which is proportionally controlled by the LIS microprocessor. The microprocessor controls the switching of a 28v DC proportional heater voltage to the lens filter heaters through the use of two M39016/12-0671 latching relays.

The use of these relays in a proportional voltage control system and switching circuits provides a simple design to handle the approximately 10W of heater power required.

12. TECHNICAL ANALYSIS

A. ADVANTAGES:

A design change would necessitate an increase in cost and a delay in the delivery schedule.

B. DISADVANTAGES:

13. Required Review: ■

INITIALS AGREE	INITIALS DISAGREE		INITIALS AGREE	INITIALS DISAGREE	
		☐ ATTITUDE CONTROL			☐ CONTRACTING OFFICER
[illegible]		■ ELECTRICAL 7/12/95	[illegible]		■ SCHEDULE MANAGER
		☐ POWER			☐ PROJECT SCIENTIST
		☐ MECHANICAL			☐ MISSION OPS MANAGER
		☐ INTEGRATION AND TEST			☐ GROUND SYSTEMS MANAGER
		☐ PROPULSION SYSTEM			☐ SOFTWARE SYSTEMS MANAGER
		☐ TEST & EVALUATION			☐ LAUNCH VEHICLE I/F MANAGER
		☐ THERMAL			☐ FLIGHT SYSTEMS I/F MANAGER
		☐ DEPLOYABLES	[illegible] B.B.		■ OTHER: LIS Inst. Mgr.
		☐ HGAS/APS			☐ OTHER:
		☐ C&DH HARDWARE			☐ OTHER:
		☐ FDS SOFTWARE			☐ OTHER:
		☐ COMMUNICATIONS			☐ OTHER:
		☐ CONTAMINATION			☐ OTHER:

14. RATIONALE FOR DISAGREEMENT:

15. RESOURCES IMPACT

		Frederick C. [illegible]	7/19/95
PROJECT SUPPORT MANAGER	DATE	FINANCIAL MANAGER	DATE

16. FUNDING PLAN:	FY ø	FY	FY	FY	FY	FY	TOTAL ø

17. CCB SIGNATURES:

Tom Keating	7/19/95	Thomas A Gallagher for	7/19/95
SYSTEMS MANAGER	DATE	DEPUTY PROJECT MANAGER	DATE
H. P. Cline	7/19/95	[illegible]	7/19/95
OBSERVATORY MANAGER	DATE	SYSTEMS ENGINEER	DATE
Richard [illegible]	7/19/95	Thomas J. [illegible]	7/19/95
INSTRUMENT SYSTEMS MANAGER	DATE	FLIGHT ASSURANCE MANAGER	DATE
Dorothy Pennington	7/19/95		
DEPUTY PROJECT MANAGER/RESOURCES	DATE		

CCB CHAIRMAN'S DECISION:

☒ APPROVE ☐ DISAPPROVE ☐ HOLD

Thomas A Gallagher	7/19/95
CCB CHAIRMAN	DATE

18. CCB CHAIRMAN'S COMMENTS:

7.3.3.3 On/Off Control

The TRMM spacecraft will provide primary power switching, through the IPSDU, for all LIS instrument non-essential power inputs. All secondary LIS instrument switching functions shall be accomplished within the LIS instrument and shall be accomplished without the use of mechanical relays unless approved by the TRMM Project. All heater control should be handled with series redundant thermostats. There shall be no LIS instrument switching of heater power except for automatic thermostatic control.

TROPICAL RAINFALL MEASURING MISSION (TRMM) SPACECRAFT TO THE LIGHTNING IMAGING SENSOR (LIS) INTERFACE CONTRAL DOCUMENT CHANGE RECORD PAGE

SYMBOL	DATE	AUTHORIZATION	REVISION/CHANGE DESCRIPTION	PAGES AFFECTED
NC	2/26/93		Initial Release	-
A	6/8/94	CCR #IN-0161, OB-0241, IN-0244, OB-0245, IN-0269 & IN-0294	Pg. vi; Para. 3.1, 3.2.1, 3.2.4, 3.2.5, 3.2.8.1, 3.2.9.6, 3.2.10.2, 3.2.10.3, 3.2.10.4, 3.2.10.7, 3.2.10.8, 3.2.10.9, 4.1.1.1, 4.2.1, 4.2.1.1, 4.3.1.1, 4.3.1.2, 4.3.1.4, 4.3.1.5, 4.3.2.1, 6.5, 6.6, 6.7, 7.1, 7.3.1, 7.3.2.4, 7.3.3.4, 7.3.3.9, 7.3.3.10, 7.4.1, 7.4.3, 7.4.4, 7.5.1, 7.5.2, 7.5.3, 8.2.2, 8.2.4, 8.4.4, 8.5, 9.5, 11; Figs. 3.2-1, 3.2-2, 3.2-3, 3.2-4, 3.2-6A, 3-2-6B, 3.2-7A, 3.2-7B, 3.2-7C, 6.5-1, 6.6-1, 7.3-1, 7.3-2, 7.3-2A, 7.4-1, 7.4-2, 7.5-6, 7.5-7, 7.7-1, 8.3-1, 8.3-2, 8.4-1, 10.5-1; Tables 3.2-1, 3.2-3A, 3.2-3B, 4.1-1, 4.1-2, 4.2-1, 4.2-2, 5.1-1, 5.2-1, 7.3-1, 7.4-1, 7.4-2, 8.4-1, 8.5-1, 10.4-1	All
B	5/24/95	CCR #IN-0374, OB-0466	Para. 3.1, 3.2.1, 7.0, 7.1, 7.2, 7.3.1, 7.3.2, 7.3.3.2, 7.3.3.4, 7.3.3.7, 7.5.1, 7.5.8, 7.5.9, 8.2.1.3, 8.2.3.1, 9.5; Figs. 3.2-1, 3.2-2, 3.2-3, 4.0-1, 4.0-2, 7.1-1, 7.1-2A, 7.1-2B, 7.3-1, 7.3-2A, 7.3-2B7.3-2C, 7.3-2D, 7.4-1, 7.4-2, 8.1-2A, 8.1-2B, 9.1-1; Tables 7.3-1, 7.4-2, Figures 7.5-6, 7.5-7	All

(FILE DIRECTLY AFTER COVER SHEET)

TROPICAL RAINFALL MEASURING MISSION (TRMM) SPACECRAFT TO THE LIGHTNING IMAGING SENSOR INSTRUMENT INTERFACE CONTROL DOCUMENT

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TRMM-490-022
Revision: B
5/24/95

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TROPICAL RAINFALL MEASURING MISSION (TRMM) SPACECRAFT TO THE LIGHTNING IMAGING SENSOR INSTRUMENT INTERFACE CONTROL DOCUMENT

APPROVED BY:

5/18/93

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TRMM Project Manager
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Date

This is a project office controlled document. Changes require the prior approval of the TRMM Configuration Control Board. Proposed changes shall be submitted to the TRMM Configuration Management Office (CMO), Goddard Space Flight Center, Code 490, Greenbelt, MD 20771.

8/15/94

Robert Markley
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Date

FOREWORD

This interface control document specifically addresses the interface design requirements of the Tropical Rainfall Measuring Mission spacecraft and the Lightning Imaging Sensor instrument.

The information in this interface control document is in accordance with the requirements specified in the Tropical Rainfall Measuring Mission System Specification: Space Segment (TRMM–490–002).

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ILLUSTRATIONS

ILLUSTRATIONS (Continued)

TABLES

ACRONYMS AND ABBREVIATIONS

ACS	Attitude Control System
AWG	American Wire Gauge
BC	Bus Controller
BOB	Breakout Box
BOL	Beginning of Life
bps	Bits per second
C	Celsius
C&DH	Command and Data Handling
CCSDS	Consultive Committee on Space Data Systems
CE	Conducted Emmissions
CERES	Clouds and the Earth's Radiant Energy System
CG	Center of gravity
cm	centimeter
cm^2	square centimeter
cm^3	cubic centimeter
CM	Configuration Management
CO_2	Carbon dioxide
CS	Conducted Susceptibility
CSM	Command Signal Module
db	Decibel
dc	Direct Current
DCM	D-bus Control Module
DG	Data Group
DSN	Deep Space Network
EGSE	Electrical Ground Support Equipment
ELV	Expendable Launch Vehicle
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EOL	End of Life
EOS	Earth Observing System
ESD	Electrostatic Discharge
FDS	Flight Data System
FEM	Finite Element Model
FOV	Field of View
g/cm^3	Grams Per Cubic Centimeter
GEVS-SE	General Environmental Verification Specification–STS/ELV
GHz	Gigahertz
GMI	Goddard Management Instruction
GMM	Geometric Math Model
GN	Ground Network
GSE	Ground Support Equipment

ACRONYMS AND ABBREVIATIONS

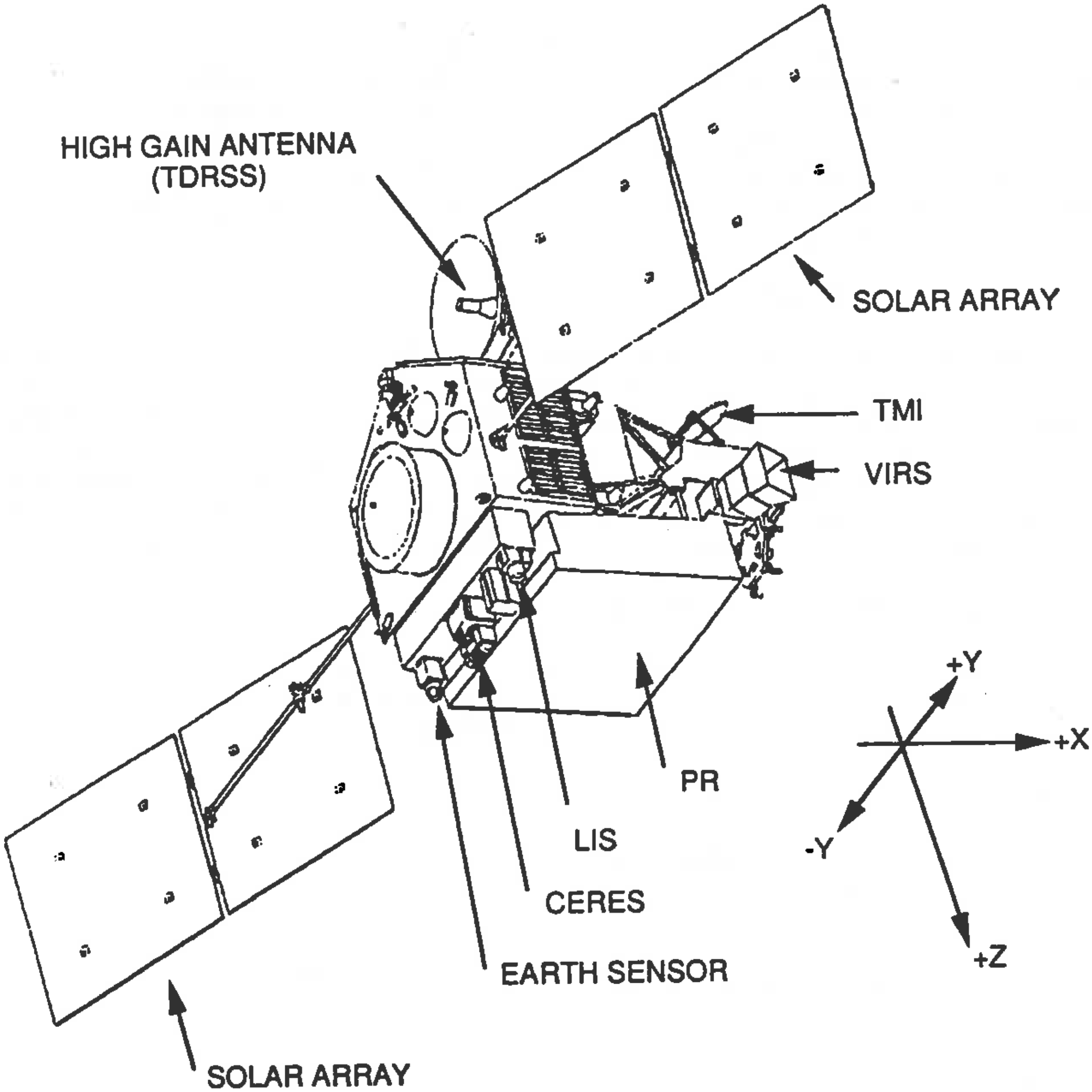
GSFC	Goddard Space Flight Center
GSTDN	Ground Station Tracking Data Network
HGA	High Gain Antenna
HPSM	High Power Switching Module
Hz	Hertz
ICD	Interface Control Document
ICS	Instrument Coordinate System
IGSE	Instrument Ground Support Equipment
IPSDU	Instrument Power Switching and Distribution Unit
JSC	Johnson Space Center
kbps	Kilobits per second
kg	kilogram
km	Kilometers
km/sec	Kilometers per second
kHz	Kilohertz
LGA	Low Gain Antenna
LIS	Lightning Imaging Sensor
LSB	Least Significant Bit
m	meter
m^2	square meter
m^3	cubic meter
mA	milliampers
max	maximum
Mbps	Megabits per second
MGSE	Mechanical Ground Support Equipment
MeV	Mega Electron Volts
MHz	Megahertz
MIL-STD	Military Standard
min	minimum
MLI	Multilayer Insulation
mm	Millimeter
ms	millisecond
MSB	Most significant bit
MSFC	Marshall Space Flight Center
N	Newton
N-M-sec	Newton-meter-second
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency of Japan

ACRONYMS AND ABBREVIATIONS

NASTRAN	NASA Structural Analysis Program
NMI	NASA Management Instruction
ns	nanosecond
Pa	Pascal(s)
PAR	Performance Assurance Requirements
PDM	Power Distribution Module
pf	picafarad
PPL	GSFC Preferred Parts List
PR	Precipitation Radar
PSDU	Power Switching and Distribution Unit
PSM	Power Switching Module
p/b	Playback
RCS	Reaction Control System
RE	Radiated Emmissions
RGMM	Reduced Geometric Math Model
RS	Radiated Susceptibility
RSS	Root Sum Square
RTMM	Reduced Thermal Math Model
R/T	Real-time
RT	Remote Terminal
RTN	Return
SIS	Spacecraft Interface Simulator
SPM	Signal Processing Module
SPSDU	Spacecraft Power Switching and Distribution Unit
STS	Space Transportation System
TBD	To be determined
TBR	To be resolved/reviewed
TBS	To be supplied
TDRSS	Tracking and Data Relay Satellite System
TICD	Thermal Interface Control Drawing
TMI	TRMM Microwave Imager
TQCM	Temperature-Controlled Quartz Crystal Microbalance
TRMM	Tropical Rainfall Measuring Mission
USA	United States of America
UT	Universal Time
UTCF	Universal Time Correlation Factor
UV	Ultraviolet
Vdc	Volts Direct Current
VF	View Factor
VIRS	Visible and Infrared Scanner

ACRONYMS AND ABBREVIATIONS

VIS	Visible
W	Watts
W/m^2	Watt (s) per square meter
µm	micrometers
µs	microsecond
µH	microhenry



NOMINAL AXES :

+X PARALLEL TO ORBITAL VELOCITY DIRECTION
- Y NORMAL TO ORBITAL VELOCITY DIRECTION
+Z NADIR DIRECTION

Figure 1.3–1
TRMM Observatory

1. INTRODUCTION

1.1 PURPOSE/SCOPE

This interface control document (ICD) defines the physical, electrical, and thermal interfaces between the Tropical Rainfall Measuring Mission (TRMM) spacecraft and the Lightning Imaging Sensor (LIS) instrument. This information shall be accurate with respect to the developmental stage of the LIS instrument and the TRMM spacecraft. It shall be used for preliminary design, and shall be the basis for the formal agreement between the Marshall Space Flight Center (MSFC), the LIS instrument developer, and the TRMM Project, located at the Goddard Space Flight Center (GSFC).

1.2 MISSION OVERVIEW

The TRMM will be a joint mission between the National Aeronautics and Space Administration (NASA) of United States of America (USA), and the National Space Development Agency of Japan (NASDA) to study the distribution and variability of precipitation and latent heat release over a multi-year data set. The TRMM observatory will be placed into a low operational altitude and low inclination orbit to provide the required high spatial resolution and necessary sampling frequency, respectively, needed for documentation of the important diurnal rainfall cycle.

1.3 OBSERVATORY DESCRIPTION

The TRMM spacecraft consists of a platform structure with all the standard support systems (power, command and data handling, attitude control) and a propulsion system. The spacecraft accommodates the following instruments:

a. Precipitation Radar (PR)

b. TRMM Microwave Imager (TMI)

c. Visible Infrared Scanner (VIRS)

d. Clouds and the Earth's Radiant Energy System (CERES)

e. Lightning Imaging Sensor (LIS)

All elements of the TRMM observatory (spacecraft and instruments) are supplied by NASA with the exception of the PR instrument, which is supplied by NASDA. The TRMM observatory is shown in Figure 1.3–1.

1.4 LIS INSTRUMENT DESCRIPTION

The LIS instrument is an optical staring telescope and filter imaging system which will acquire and investigate the distribution and variability of both intracloud and cloud-to-ground lighting over the Earth. The data from the LIS instrument can be correlated to the global rates, amounts, distribution of precipitation, and the release and transport of latent heat.

1.5 PRECEDENCE

In the event of conflict between the TRMM Systems Specification Space Segment (TRMM-490-002) and this document or other documents referenced herein, the contents of TRMM-490-002 shall take precedence. In the event of conflict between the referenced documents, excluding TRMM-490-002, and the contents of this document, the contents of this document shall take precedence.

1.6 CHANGE AUTHORITY

This document shall be formally approved and controlled in accordance with the provisions of the Configuration Management (CM) procedures as established by the TRMM Project Office. The details of these procedures are defined in the TRMM Configuration Management Plan (TRMM-490-007).

1.7 DOCUMENT ORGANIZATION

This ICD is organized into eleven sections as described below:

a. Section 1: Specifies the intent and contents of this document. Overviews are provided for the TRMM mission, the TRMM spacecraft, and the LIS instrument. It also discusses the change process, the requirements precedence, and the applicable terminology as related to this document.

b. Section 2: Specifies the government and non-government documents used in developing this document.

c. Section 3: Specifies the mechanical interface requirements between the TRMM spacecraft and the LIS instrument. It also includes general interface descriptions and responsibilities with regard to the LIS instrument.

d. Section 4: Specifies the thermal interface requirements between the TRMM spacecraft and the LIS instrument.

e. Section 5: Specifies an overview of the modes of operation for both the TRMM spacecraft and the LIS instrument.

f. Section 6: Specifies the environmental requirements for the TRMM spacecraft and the LIS instrument.

g. Section 7: Specifies the electrical interface requirements between the TRMM spacecraft and the LIS instrument.

h. Section 8: Specifies the command and data handling (telemetry) interface requirements between the TRMM spacecraft and the LIS instrument.

i. Section 9: Specifies the contamination and storage and operations requirements for the TRMM spacecraft and the LIS instrument

j. Section 10: Specifies the integration, test, and verification requirements for the TRMM spacecraft and the LIS instrument.

k. Section 11: Specifies the safety requirements between the TRMM spacecraft and the LIS instrument.

1.8 DEFINITIONS

The following are definitions of terms used within this document.

1.8.1 General Definitions

a. Bonding: The process of connecting together metal parts so they make low resistance contact.

b. Broadband Emission: That which has a spectral energy distribution sufficiently broad, uniform, and continuous, so the response of the measuring receiver does not vary significantly when tuned over a specified number of receiver impulse bandwidth.

c. Conducted Emission: Desired or undesired electromagnetic energy which is propagated along a conductor. Such an emission is called "conducted interference" if it is undesired.

d. Electromagnetic Compatibility: The capability of electronic equipment or systems to be operated with a defined margin of safety in the intended operational environment at designed levels of efficiency without degradation due to interference.

e. Grounding: The bonding of an equipment case, frame, or chassis to vehicle structure to ensure a common potential.

f. Instrument Complement: The collection of one or more instruments mounted on the TRMM spacecraft.

g. Narrowband Emission: That which has its principal spectral energy lying within the bandpass of the measuring receiver.

h. Observatory: The fully integrated spacecraft comprised of the spacecraft bus and the instrument complement.

i. Primary Power: The power service originating at the TRMM spacecraft power system and connected to all spacecraft subsystems, instruments, and all survival heaters (through the power switching and distribution unit).

j. Radiated Emission: Desired or undesired electromagnetic energy which is propagated through space. Such an emission is called "radiated interference" if it is undesired.

k. Secondary Power: The power service using an isolated interconnection to the primary power bus to insure a specified isolation from the primary power service.

l. Spacecraft: The complement of engineering subsystems required to support the mission, including subsystems, structure, harnessing, and non-replaceable equipment. This does not include the TRMM instrument complement.

m. Transient: Single-shot impulses or pulses of low repetition rates generated by a switching action, by relay closures, or by other cyclic events.

1.8.2 Verification Method

a. Inspection: The process of measuring, examining, gaging, or otherwise comparing an article or service with specified requirements.

b. Analysis: A verification method using techniques and tools such as math models, similarity assessments, and validation of records, to confirm that verification requirements have been satisfied.

c. Demonstration: A method of verification denoting the qualitative determination of properties of an end-item or component by observation. Demonstration is used with or without special test equipment or instrumentation to verify requirement characteristics.

d. Tests: Measurements made under fully controlled and traceable conditions using simulated environments and external stimuli, or measurements of a system or equipment taken in the field in which actual or representative environments and external stimuli are used.

2. APPLICABLE/REFERENCE DOCUMENTS

2.1 APPLICABLE DOCUMENTS

Document Number	Title
TRMM-490-002	TRMM System Specification - Space Segment Specification

2.2 REFERENCE DOCUMENTS

Document Number	Title
TRMM-490-001	TRMM Mission Specification
TRMM-490-007	TRMM Configuration Management Plan
TRMM-490-082	Observatory Low Power Mode/Safe Hold Architecture and Process Description Document
	Orbital Environment for the TRMM Mission, EnviroNet, the Space Environment Information Service, GSFC, July 1992.
TRMM-733-043	TRMM Electrical Subsystem Specification
TRMM-733-104	"Tropical Rainfall Measuring Mission Instrument Ground Support Equipment To Spacecraft Ground Support Equipment Interface Control Document"
TRMM-733-105	"Tropical Rainfall Measuring Mission Spacecraft Interface Simulator Description"
TRMM-303-006	Performance Assurance Requirements (PAR) for TRMM
GEVS-SE	General Environment Verification Specification – Space Transportation System (STS)/Expendable Launch Vehicle (ELV)
PPL-19 and subsequent	Goddard Space Flight Center (GSFC) Preferred Parts List
NMI 8010.2A	NASA Management Instruction (NMI) 8010.2A, Use of Metric System of Measurement in NASA programs.

NMI 8010.1A	Classification of NASA Payloads. Predicted Solar Data, Kenneth H. Schattan, NASA, GSFC, Code 910.1, Greenbelt, MD 20771.
GMI 8010.2	Classification of GSFC Orbital Flight Projects and Determination of Commensurate Performance Assurance Requirements.
CCSDS 101.0-B-2	"Recommendation for Space Data Systems Standards. Telemetry Channel Coding," CCSDS Recommendation, Blue Book, January 1987.
CCSDS 102.0-B-2	"Recommendation for Space Data Systems Standards. Packet Telemetry," CCSDS Recommendation, Blue Book, January 1987.
CCSDS 201.0-B-1	"Recommendation for Space Data Systems Standards. Telecommand, Part 1: Channel Service, Architectural Specification," CCSDS Recommendation, Blue Book, January 1987.
CCSDS 202.0-B-1	"Recommendation for Space Data Systems Standards. Telecommand, Part 2: Data Routing Service, Architectural Specification," CCSDS Recommendation, Blue Book, January 1987.
CCDSD 301.0-B-2	CCSDS Recommendations for Space Data Systems Standards, Time Code
CCSDS 203.0-B-1	"Recommendation for Space Data Systems Standards. Telecommand, Part 3: Data Management Service, Architectural Definition," CCSDS Recommendation, Blue Book, January 1987.
CCSDS 701.0-B-1	"Recommendation for Space Data Systems Standards. Advanced Orbiting Systems, Network and Data Links: Architectural Specification," CCSDS Recommendation Blue Book, October 1989.Charged Particle Exposure of TRMM, Methods 2 X-900-90-02, June 1990.
MIL-STD-461C	Military Standard: Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interface
MIL-STD-462	Military Standard: Electromagnetic Interference Characteristics

MIL-STD-463A	Military Standard: Definitions and System of Units, Electromagnetic Interference and Electromagnetic Compatibility Technology
MIL-STD-1773	Military Standard: Fiber Optics Mechanization of An Aircraft Internal Time Division Command/Response Multiplex Data Bus
NASA SP-8013	Meteoroid Environment Model-1969 (Near Earth to Lunar Surface), NASA Space Vehicle Design Criteria (Environment), March 1969.
X-900-90-02	Charged Particles Exposure of TRMM, Method 2, June 1990.

3.2.1 Mechanical Interface Drawings

Figures 3.2–1, 3.2–2, and 3.2–3 are the TRMM Dimensional Control Drawings. They contain the LIS instrument configured to the TRMM spacecraft and are included for reference only. The Mechanical Interface Control Drawings (Figures 3.2–4 thru 3.2–6A and B) and the LIS Mechanical Installation Drawings 3.2–7A, B, and C provide detailed LIS instrument interface information. All Mechanical Interface Drawings are signed off with the current version contained in the Mechanical Drawing Annex.

A seperate Mechanical Drawing Annex will be created and maintained to hold current full size mechanical drawings and red-lined copies. The Mechanical Drawing Annex will consist of the following drawings:

a. GSFC LIS Mechanical Interface/Envelope Control Drawing

b. LIS Mechanical Installation Drawing

c. MSFC Mechanical Interface Control Drawing

3.2.2 Metrication

All dimensions of the LIS instrument shall be metric except any portion based on existing designs may be exempt from the metric requirements.

3.2.3 Accessibility and Maintainability

The design of the LIS instrument shall permit easy accessibility to test points and components that may require adjustment. The accessibility requirement shall apply for the period of integration of the LIS instrument with the spacecraft and for the checkout of the spacecraft. Special tools and handling fixtures for servicing or adjusting the LIS instrument shall be delivered with the LIS instrument. Any field-removable parts shall be keyed to ensure proper re-assembly and alignment.

The LIS instrument has no special servicing requirements. Access to the LIS instrument test connectors is required during integration and testing at both GSFC and the launch facility. The covering protecting the Sensor assembly (a red tag item) will need to be removed and a final lens cleaning will need to be accomplished prior to launch. J8, 9, 10, 11, 12, and 21 are the LIS test connections and their locations on the Electronics Assembly are indicated in Figure 3.2–6A.

3.2.4 Mounting Characteristics

The LIS instrument mounting locations and installation drawings are shown in Figure 3.2–4 and Mechanical Interface Control Drawings 3.2-7A, B, and C.

The mounting hardware for both flight and testing will be supplied by MSFC.

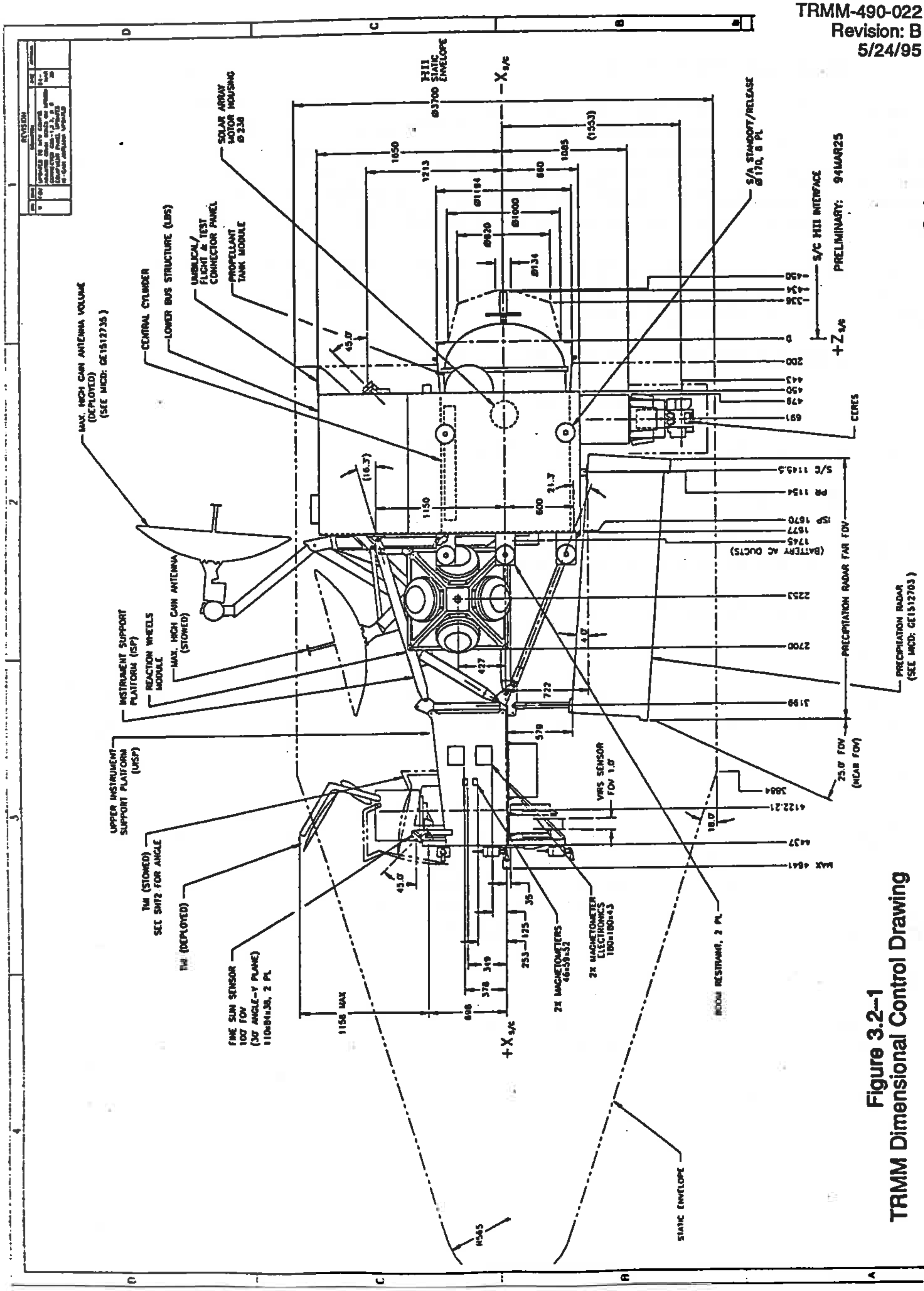


Figure 3.2–1
TRMM Dimensional Control Drawing

For Reference Only

For Reference Only

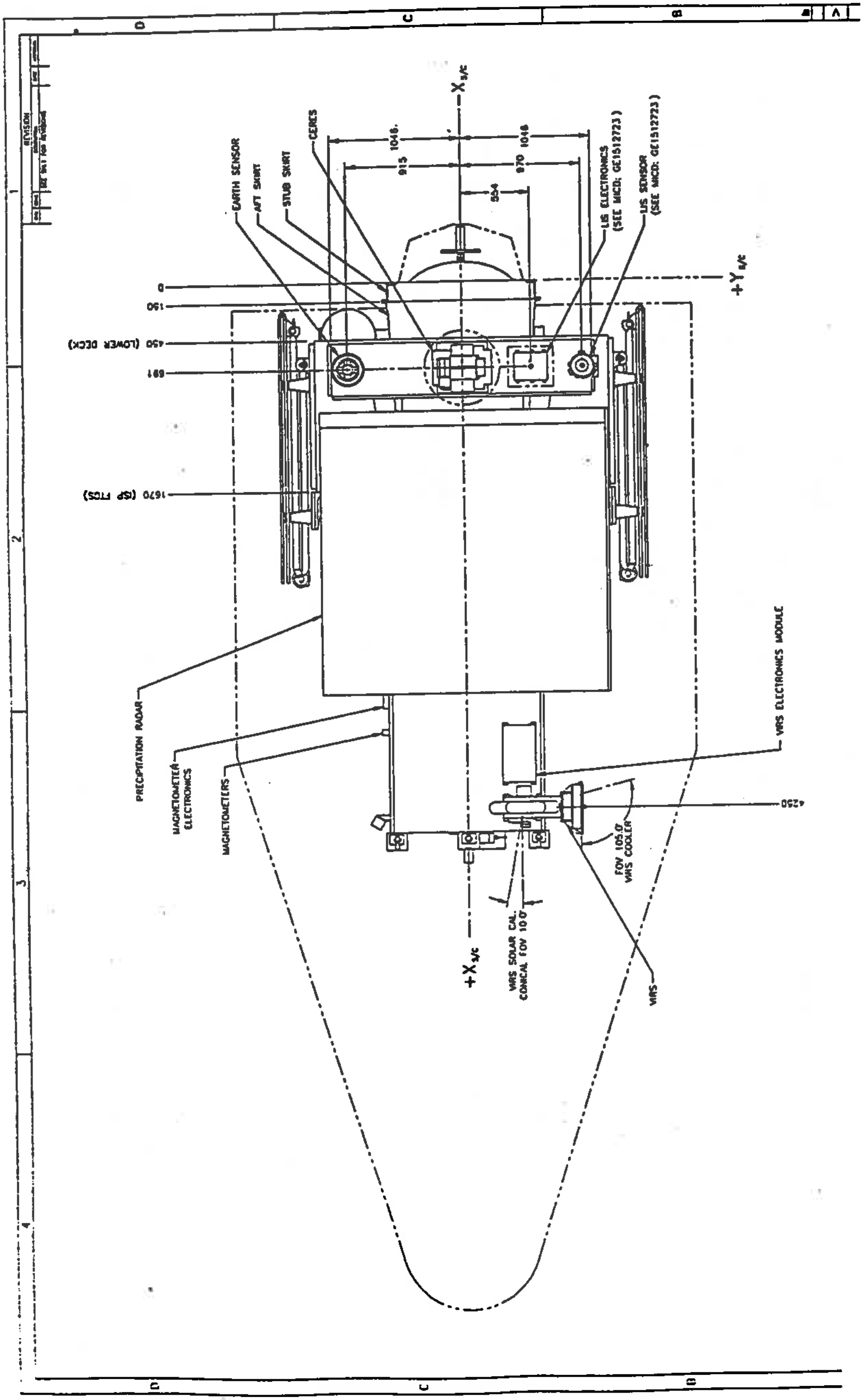
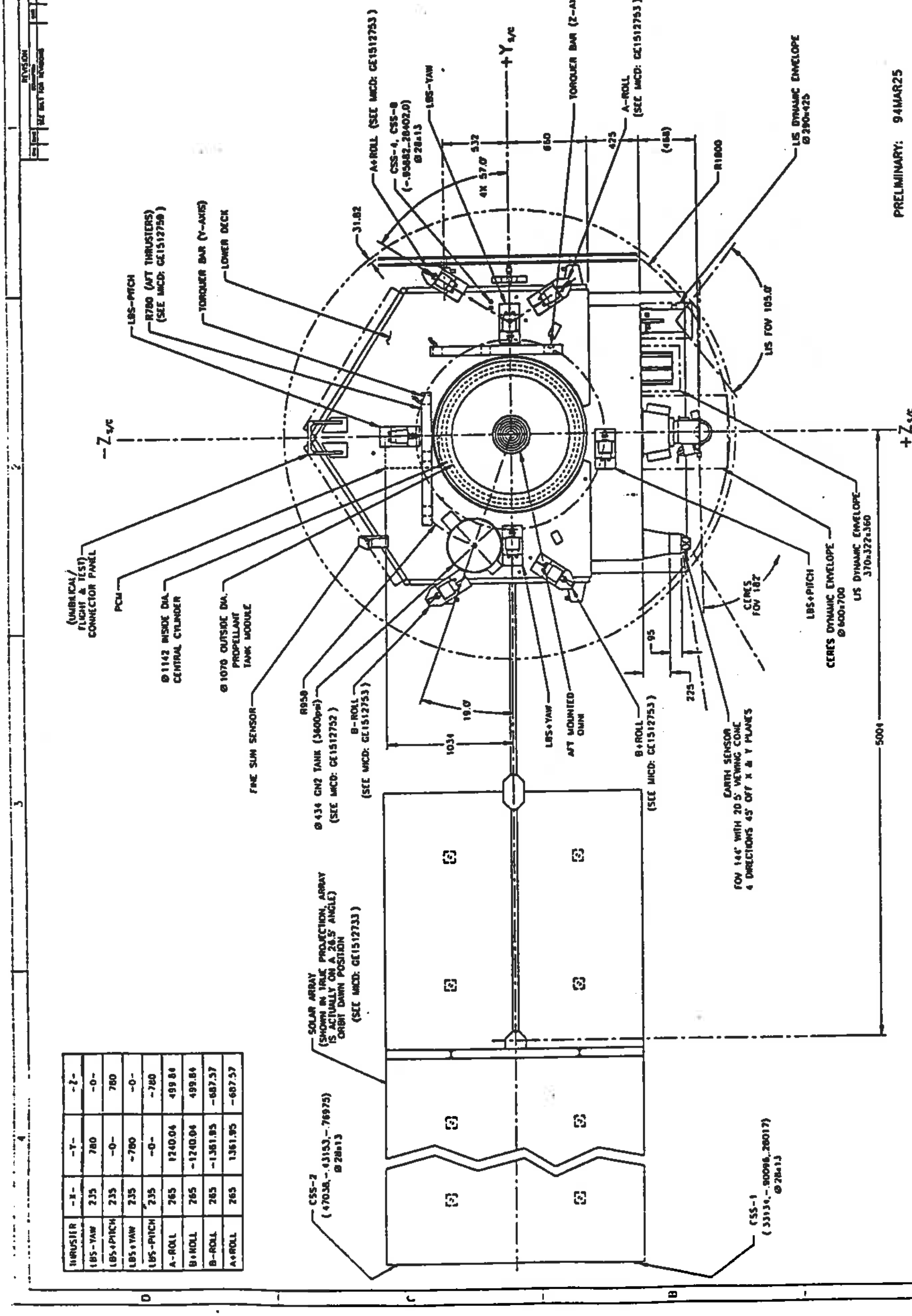


Figure 3.2–3
TRMM Dimensional Control Drawing



THRUSTER	-X-	-Y-	-Z-
LBS-YAW	235	780	-0-
LBS+PITCH	235	-0-	780
LBS+YAW	235	-780	-0-
LBS-PITCH	235	-0-	-780
A-ROLL	265	1240.04	499.84
B+ROLL	265	-1240.04	499.84
B-ROLL	265	-1361.85	-687.57
A+ROLL	265	1361.85	-687.57

Figure 3.2-2
TRMM Dimensional Control Drawing

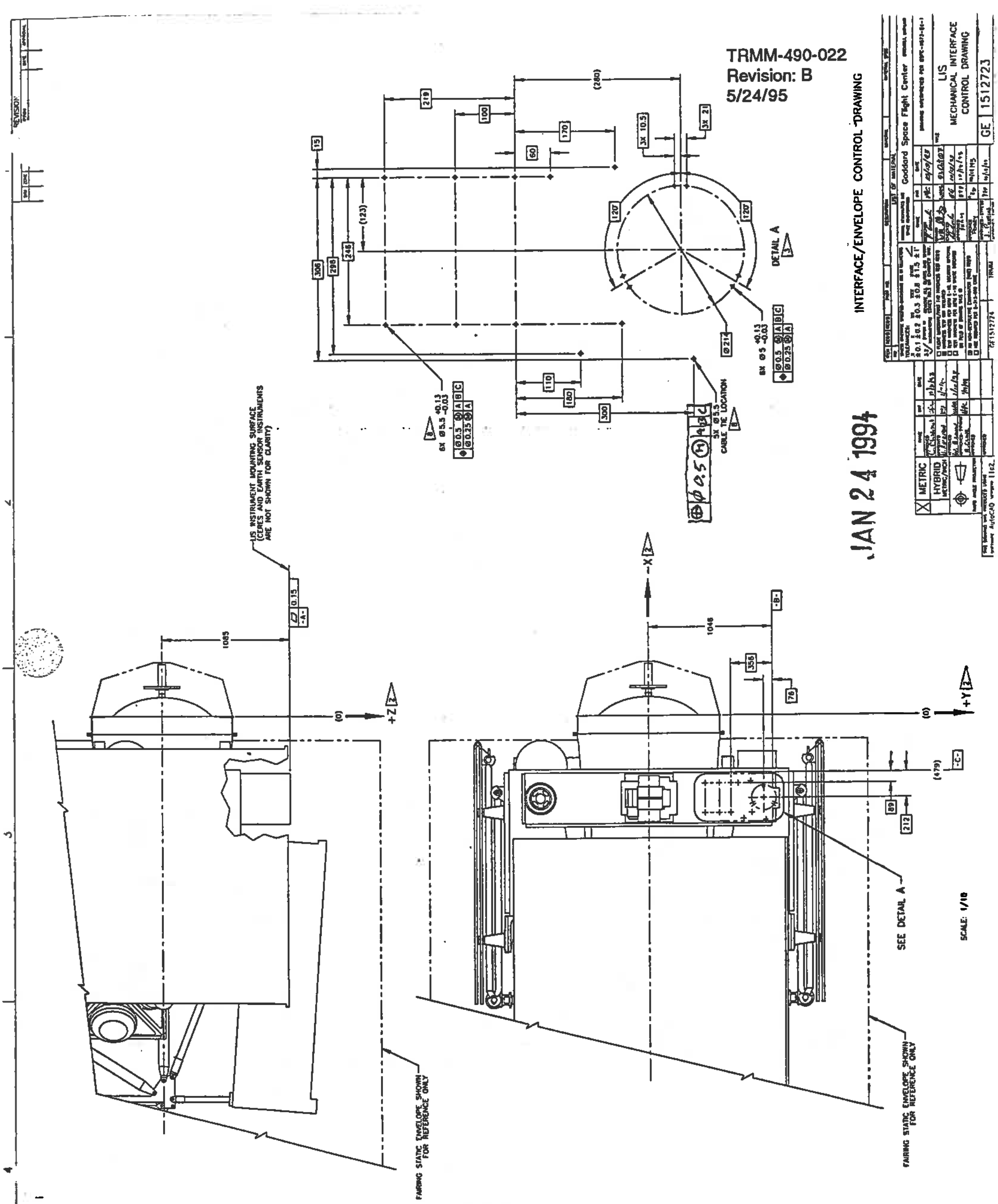


Figure 3.2–4
LIS Mechanical Interface Control Drawing

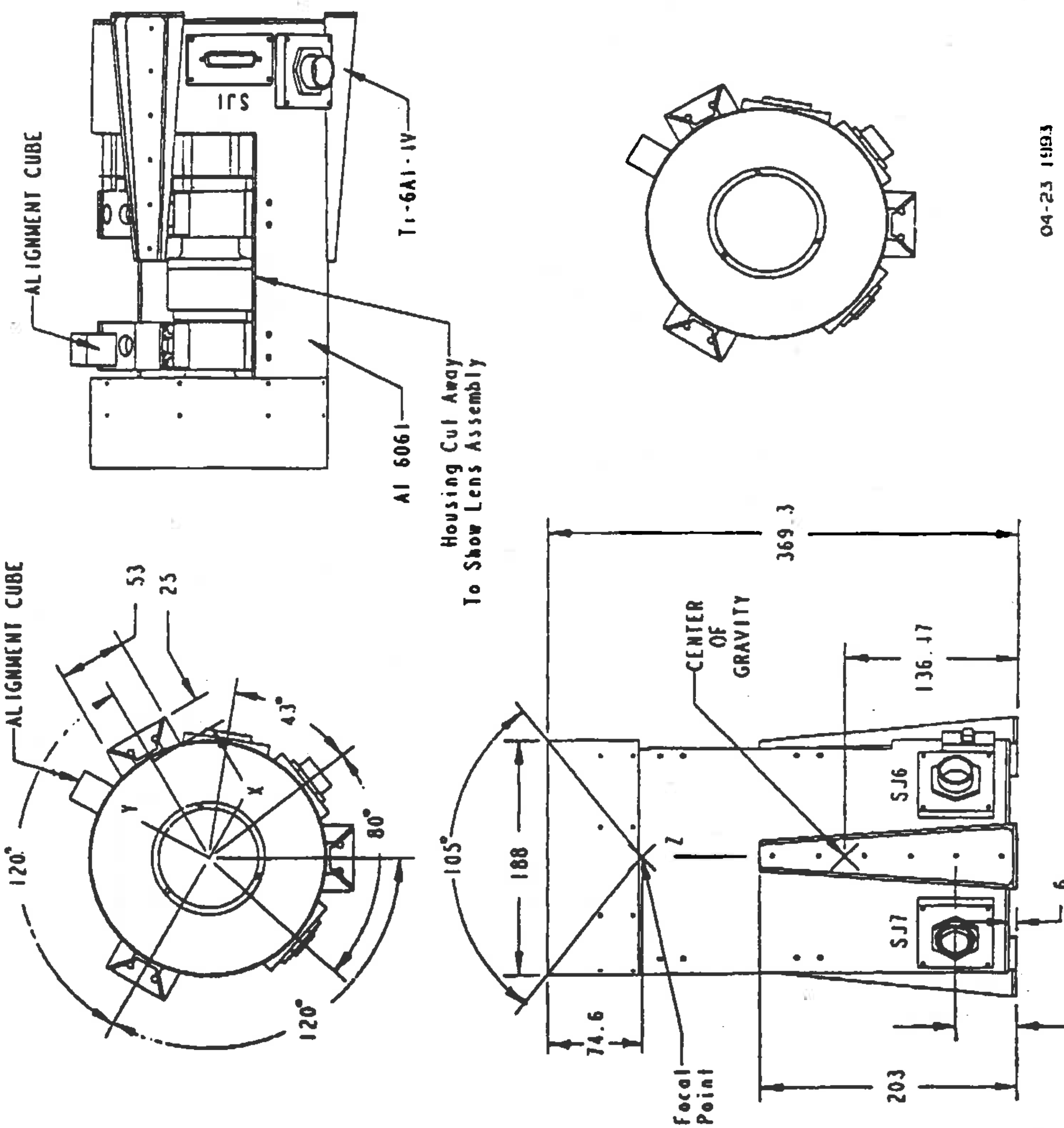


Figure 3.2–5
Mechanical Interface Drawing - Sensor Assembly

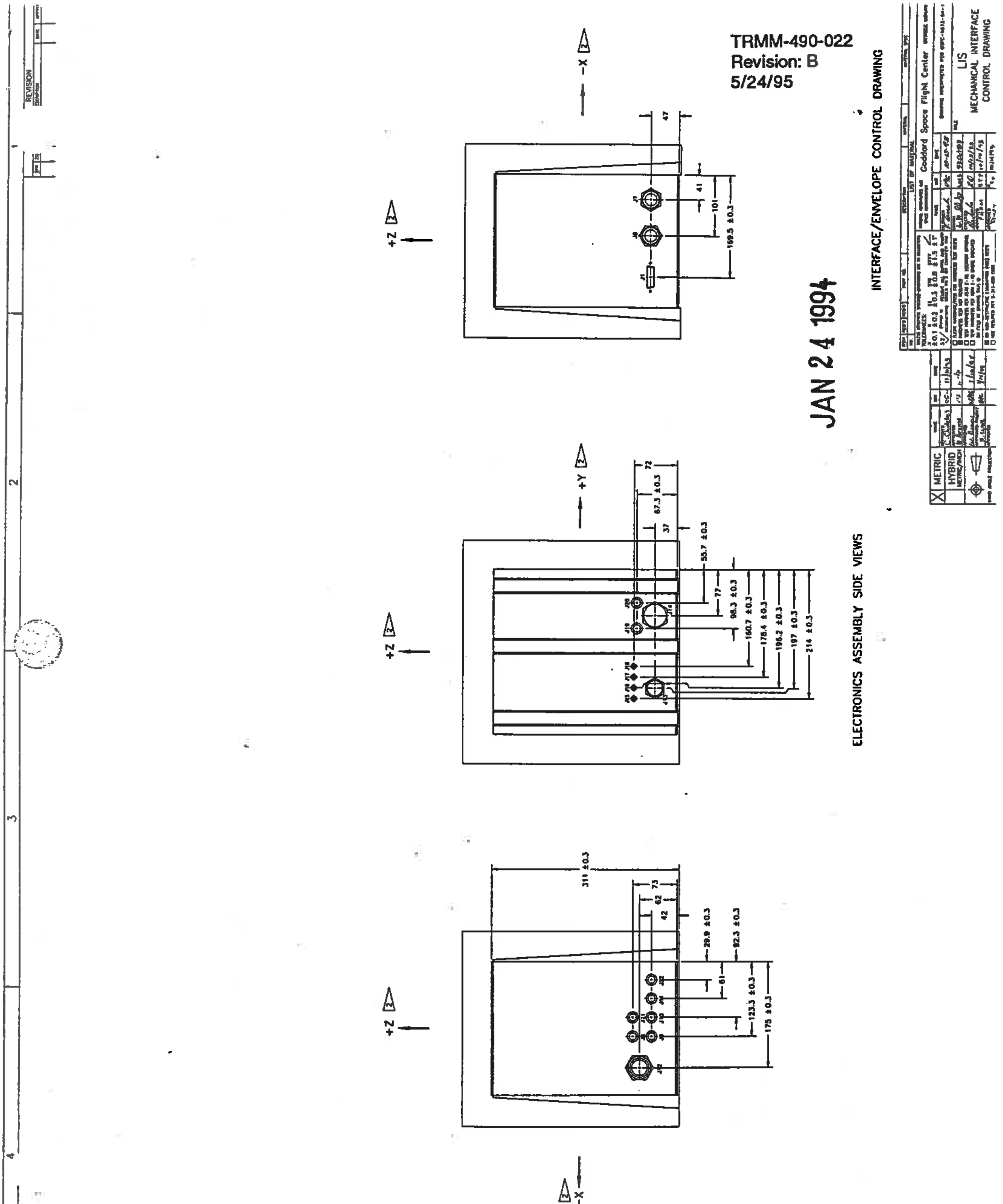


Figure 3.2–6A
Mechanical Interface Control Drawing - Electronics Assembly

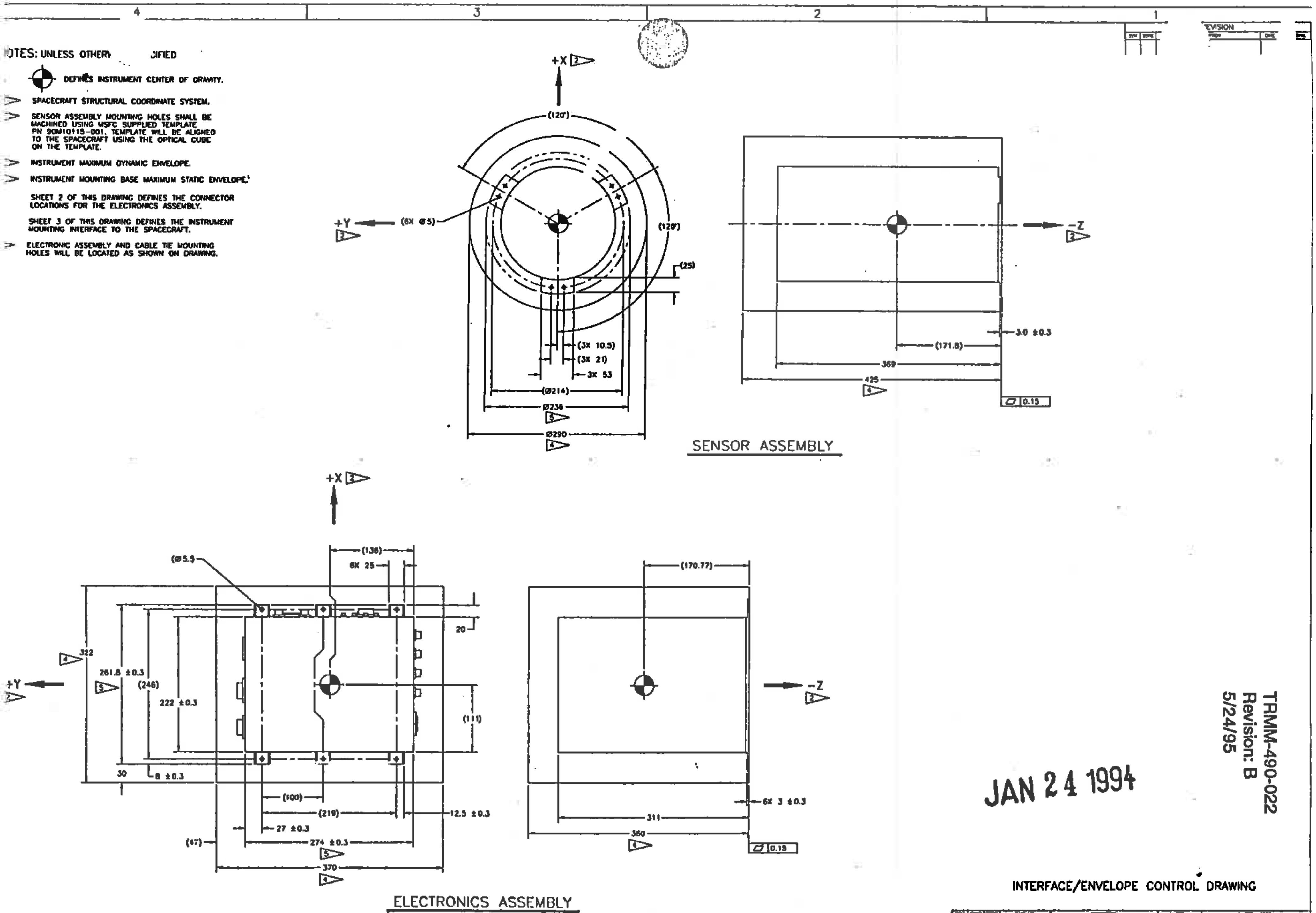


Figure 3.2–6B
LIS Mechanical Interface Control Drawing

3.2.5 Mounting Envelope

The LIS instrument shall be contained within a volume no greater than the following:

Electronics Box		Sensor	
Height	370mm	Height	425mm
Length	322mm	Circular Diameter	290mm
Width	316mm		

Maximum dynamic envelope is shown in Figure 3.2–6A and 6B.

3.2.6 Mass Properties

3.2.6.1 Center of Mass

The nominal center of mass location and coordinates are shown in Figure 3.2–5 and 3.2–6. The measured tolerances on the center of mass location shall be ± 2 millimeters (mm) in the X direction, ± 2mm in the Y direction, and ± 2mm in the Z direction. The measured center of mass shall be provided with the delivery of the LIS instrument.

3.2.6.2 LIS Mass Allocation

The total mass of the LIS instrument, including instrument cables and mounting hardware, shall not exceed 21 kg. The measured mass shall be provided with the delivery of the LIS instrument to within ±1 percent.

3.2.6.3 Moments of Inertia

The LIS instrument moments of inertia shall be about axes parallel to the spacecraft X, Y, and Z axes but passing through the instrument's center of mass.

At LIS instrument delivery, the moments of inertia shall be supplied with an accuracy of ±10 percent. These values can be determined through testing or through analysis. If determined analytically, verification of the analytical method shall be supplied.

3.2.6.4 DELETED LIS HAS NO MOVING PARTS.

3.2.7 Field of View

The conical Clear Field of View (CFOV) required by the LIS instrument is 105°. The instrument CFOV is shown in Figure 3.2–5. The spacecraft shall provide mounting of the instrument to ensure that the required CFOV is not obstructed.

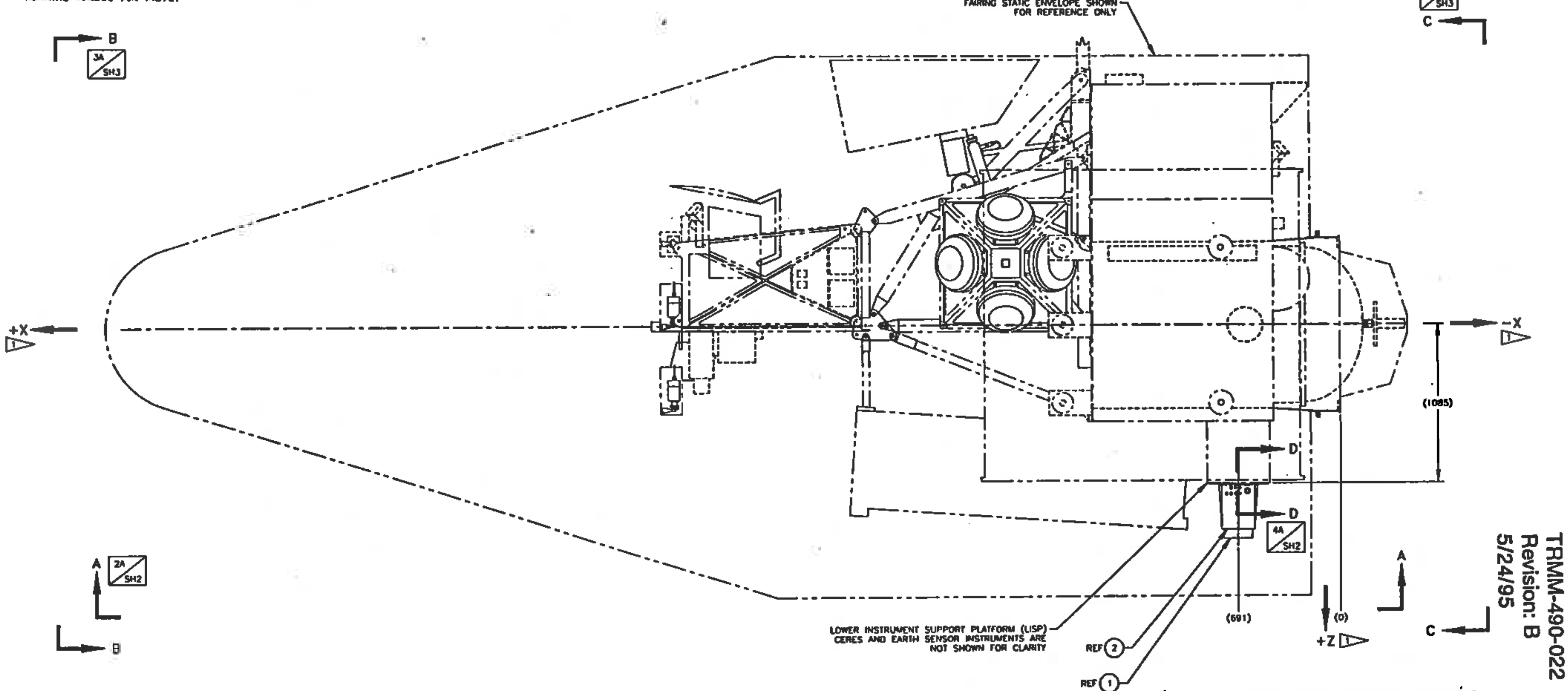
3.2.8 Coordinate Axes Definition

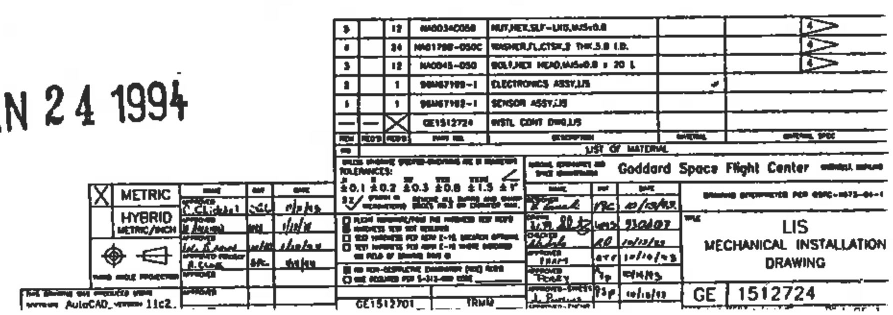
3.2.8.1 Instrument Coordinate System

The instrument coordinate system (ICS) is depicted in Figure 3.2–5 and 3.2–6A and 6B. The

NOTES: UNLESS OTHE[illegible] .CIFIED

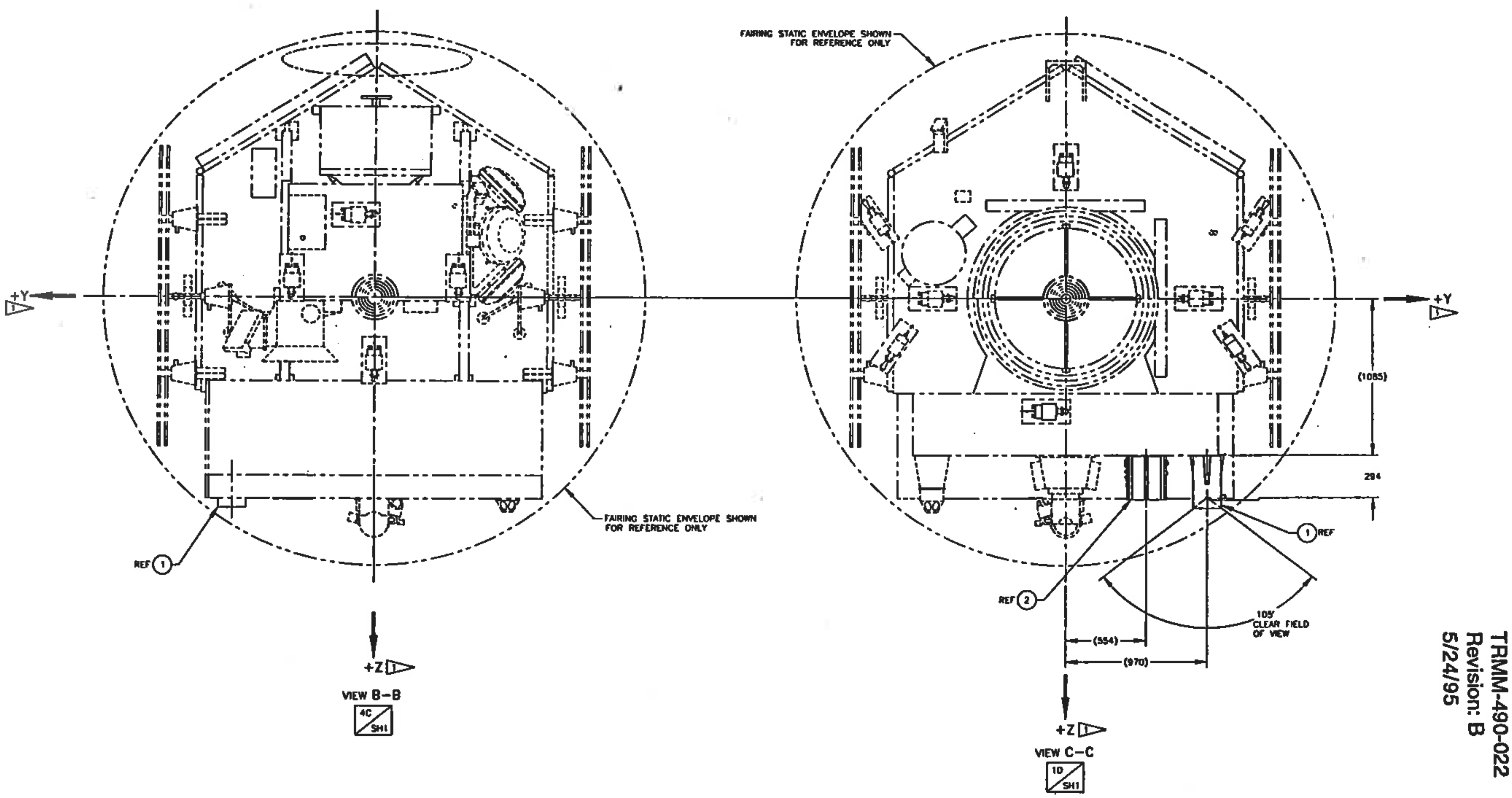
1. SPACECRAFT STRUCTURAL COORDINATE SYSTEM.
2. THE MAXIMUM AMOUNT OF MISALIGNMENT AT INSTALLATION BETWEEN THE BORESITE AND THE NORMAL TO THE INSTRUMENT MOUNTING PLANE, WHICH WILL BE CORRECTED FOR, WILL BE ±12 ARC MINUTES.
3. THE INSTRUMENT BORESITE WILL BE ALIGNED TO THE SPACECRAFT REFERENCE AXIS WITHIN ±12 ARC MINUTES.
4. HARDWARE SHALL BE SUPPLIED BY MSFC.
5. FOR INTERFACE/ENVELOPE CONTROL DRAWING REFER TO GE1512723.
6. TORQUE TO TBD N-M ABOVE RUNNING TORQUE PER MSFC.





JAN 24 1994

Figure 3.2–7A
LIS Mechanical Installation Drawing



INSTALLATION CONTROL DRAWING

JAN 24 1994

Goddard Space Flight Center

METRIC
HYBRID

LIS MECHANICAL INSTALLATION DRAWING

GE 1512724

Figure 3.2–7B
LIS Mechanical Installation Drawing

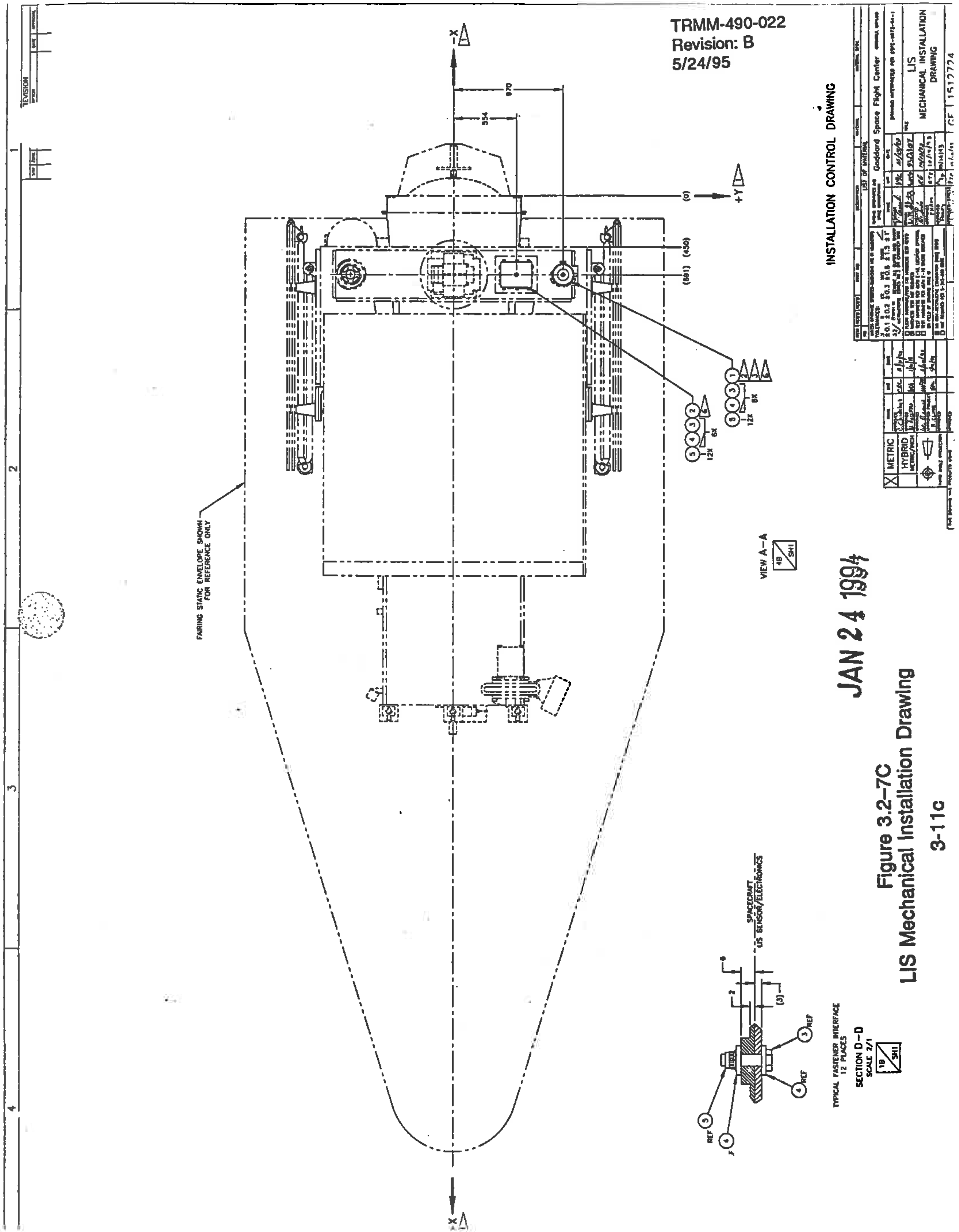


Figure 3.2-7C
LIS Mechanical Installation Drawing

ICS shall be oriented and aligned with the observatory reference coordinate system as shown in Figure 1.3–1. The +Z-axis of ICS is the nadir direction. The origin is located at the intersection of the Z axis with the surface of the instrument which mates with the surface of the spacecraft. The ICS +X axis is aligned with and in the same direction as the observatory reference +X axis. The ICS Y axis is consistent with the right-hand rule.

3.2.9 Alignment Requirements

3.2.9.1 Placement Accuracy

A LIS-provided drill template shall be used to drill both the LIS instrument and the spacecraft mounting holes. During installation of the LIS instrument, the LIS instrument reference ("boresight") axes shall be aligned to within ± 12 arcminutes (3σ/axis) of the spacecraft reference axes. This accuracy can be attained only when the LIS reference ("boresight") axes are parallel to within ± 12 arcminutes of the normal to the instrument mounting plane. MSFC shall provide the known (measured) bias between LIS "boresight" and optical cube axes. GSFC's pointing error analyses do not include internal instrument errors due to measurement inaccuracies, temperature shifts, etc.

3.2.9.2 Alignment Knowledge

The precision of the measurement of the alignment between the instrument reference axes and the observatory reference coordinate axes shall be less than ±30 arcsec ($3\ \sigma$/axis). The measurement of the alignment between the instrument reference axes and the observatory reference axes is the responsibility of the GSFC. This measurement shall be supplied to MSFC.

3.2.9.3 Alignment Reference

The LIS instrument shall provide optical reference surfaces (alignment cube) adequate to make the aspect measurements described above. Instrument optical reference surfaces shall consist of at least two nearly orthogonal reflecting surfaces, suitable for use with autocollimating devices, so that they are readily visible at the time of instrument-to-spacecraft integration. The LIS instrument shall provide instrument boresight at nadir with respect to the coordinate system as defined by the +Z and -X optical reference surfaces. The knowledge and accuracy requirements presented in the following paragraphs shall be between the instrument optical alignment reference and the stated observatory reference. The optical reference cube interface is shown in Figure 3.2–5.

3.2.9.4 Pointing Accuracy

The TRMM observatory shall provide the capability of pointing the instrument alignment cube to within ± 24 arcminutes ($3\ \sigma$/axis) with respect to the orbit normal and the horizon bisector.

3.2.9.5 Pointing Knowledge

The knowledge of instrument pointing attitude (of the alignment cube) shall be accurate to within ±12 arcminutes (3 σ/axis). This tolerance represents the root-sum-square of the alignment knowledge uncertainties including errors due to measurement uncertainties, thermal deformation, gravity effects, and launch shifts.

3.2.9.6 Pointing Stability

The maximum excursion, peak-to-peak, of the observatory reference axis during nominal mission mode shall be ±6 arcminutes (3 σ/axis) over a time interval of one second.

3.2.9.7 Attitude Control System Pointing Reference

The pointing control and knowledge of the TRMM observatory is with respect to the orbit normal and the locus of points on the Earth's surface that would be traced out by an ideal horizon sensor viewing a perfect carbon dioxide (CO_2) horizon of an ellipsoidal Earth. This locus of points (the horizon bisector) will generally not coincide with the geodetic or geocentric local vertical. The attitude control system (ACS) will control the spacecraft to the horizon bisector. The relationship of this control point to the geodetic or geocentric local vertical can be derived from the spacecraft ephemeris.

3.2.10 Structural/Dynamic Computer Modeling

3.2.10.1 Finite Element Models

All finite element models (FEMs) should be delivered in standard SI units using meters (m) for length, kilograms (kg) for mass, and Newtons (N) for force; therefore, all modulus of elasticity and shear should be in N/m^2 and material density in kg/m^3. All models shall be delivered in NASA Structural Analysis (NASTRAN) bulk data format. A test-verified FEM should be delivered if detailed on-orbit alignment predictions are required, or if the fixed based natural frequency is less than 50 Hz.

3.2.10.2 Pressure

The LIS instrument shall be shown by analysis to have positive margin at loads equal to twice those induced by the maximum expected pressure differential during launch. The expected pressure profile for the H-II is shown in Figure 3.2–8. The analysis shall estimate the pressure differential induced by the nominal launch trajectory across elements susceptible to such loading (e.g., thermal blankets, contamination enclosures, and housings). If analysis does not indicate a positive margin, then testing is required.

3.2.10.3 Design Limit Load Factors

Limit load is defined as the maximum load ever experienced by the structure. The design limit loads for the LIS instrument are defined in Table 3.2–1.

Table 3.2–1
Design Limit Load Factors

Component	Translation (G's)		
	X-Axis	Y-Axis	Z-Axis
LIS Instrument	7.0	3.4	3.4

All loads are to be applied simultaneously in all plus/minus combinations.

Note: The qualification (protoflight) strength test levels should be performed at 1.25 times the above noted design limit loads. Acceptance levels should be performed (for structural reliability) at 1.0 times the above noted design limit loads.

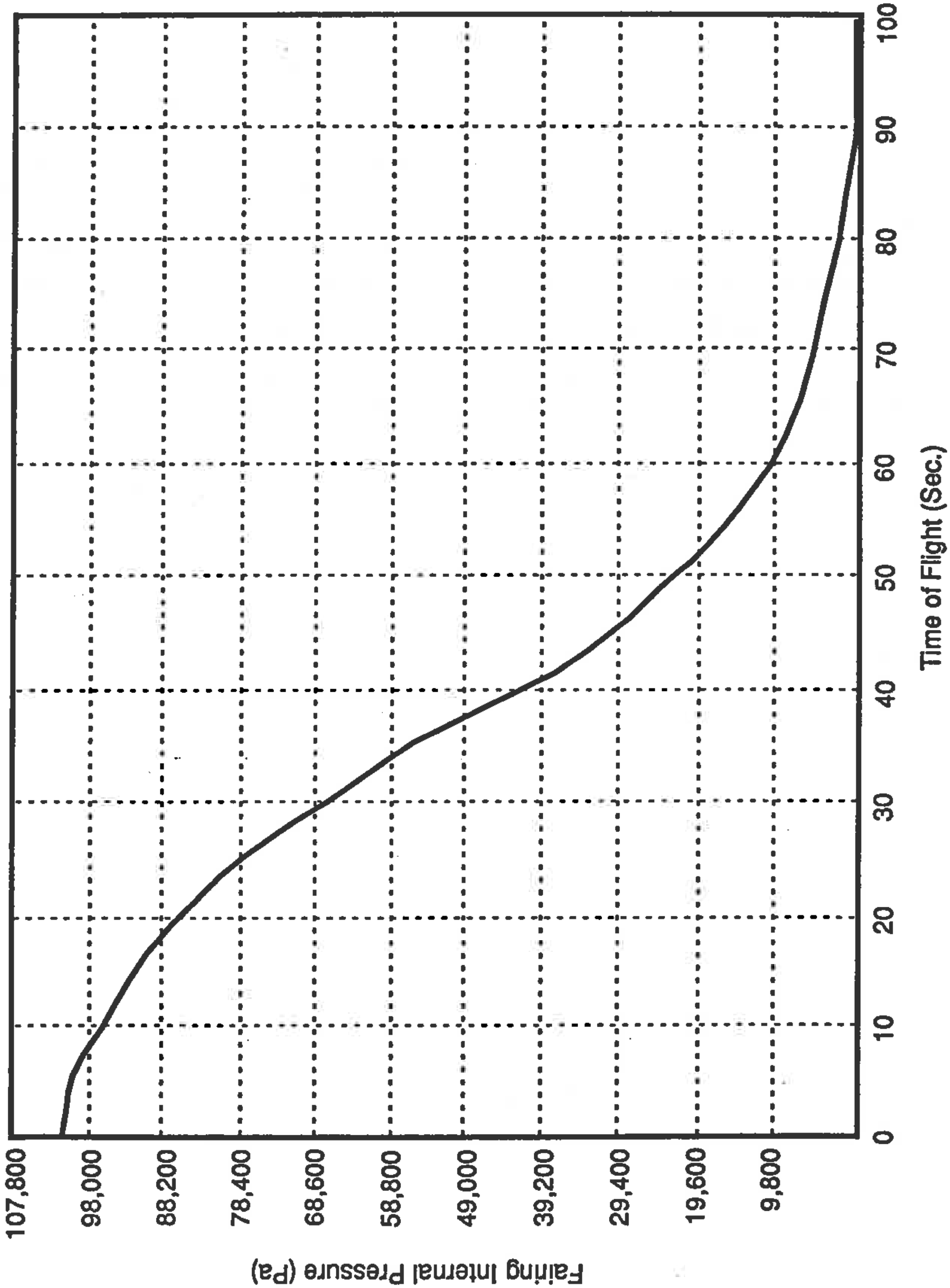


Figure 3.2–8
Fairing Internal Pressure Profile

3.2.10.4 Natural Frequency Requirements

The LIS instrument shall have a fixed base natural frequency greater than 50 Hz. The 50 Hz minimum frequency shall be verified by a low level sine sweep while this instrument is set up for the random vibration test. If the frequency is less than 50 Hz, a test-verified FEM and GSFC approval of the minimum frequency is required.

3.2.10.5 Factors of Safety for Structural Design

The structural design of all mounting hardware and/or bracketry (or any other structure which could be affected by flight loads) shall ensure a factor of safety ≥1.4 for ultimate based on limit loads and qualification by test as indicated in the TRMM Performance Assurance Requirements (PAR), TRMM-303-006.

Strength shall be demonstrated in accordance with the GEVS-SE. The structural strength shall be verified by test at 1.25 times the specified design limit load factors.

3.2.10.6 Structural Reliability

Structural reliability and fracture control shall be per the TRMM PAR. Demonstration of fracture control, or a proof-loads test can be performed to expected flight limit levels, or a combination of the two methods may be applied.

3.2.10.7 Random Vibration

Table 3.2–2 specifies the random vibration test for the LIS instrument at the instrument level.

3.2.10.8 Shock Input

The shock spectrum shown in Figure 3.2–9 is the expected input at the base of the LIS instrument due to TRMM spacecraft separation clampband actuation and should be used for analysis purposes only. Due to the risk in over testing the LIS instrument using an electrodynamic shaker, this shock test will be deferred to the observatory level where the flight pyro's will be fired. All other pyro's including solar arrays and instrument, will be fired at the observatory level.

Table 3.2–3B
Acceptance Sine Sweep Test Levels For LIS Instrument

Axis	Frequency (Hz)	Level
X	5.0 - 6.1 6.1 - 50.0	0.5" D.A. ± 0.95 g
Y	5.0 - 6.25 6.25 - 33.0 33.0 - 50.0	0.5" D.A. ± 1.0 g ± 0.4 g
Z	5.0 - 5.6 5.6 - 33.0 33.0 - 50.0	0.5" D.A. ± 0.8 g ± 0.4 g

Note: 1. Sweep rate 4 octaves per minute.

2. If required, the above levels should be notched for acceptance units to not exceed the design limit load, and for protoflight units to not exceed 1.25 times the design limit load

Table 3.2–2
LIS Random Vibration Levels (3 axis)
(Test Durations: 1 minute per axis)

Frequency (Hz)	Acceptance (G^2/Hz)	Frequency (Hz)	Protoflight (G^2/Hz)
20 - 80	0.04	20 - 250	0.08
80 - 160	+ 3 dB/OCT	250 - 630	+ 3 dB/ OCT
160 - 500	0.08	630 - 1000	0.20
500 - 630	+3 dB/OCT	1000 - 2000	-9 dB/OCT
630 - 1000	0.1	2000	0.0252
1000 - 2000	- 9 dB/OCT		
2000	0.0125		
Overall G's (rms)	11.0	Overall G's (rms)	14.8

3.2.10.9 Sine Vibration

The LIS instrument will be subjected to the following protoflight and acceptance sine sweep test level vibration environments in three orthogonal axes described in Tables 3.2–3A and 3.2-3B.

Table 3.2–3A
Protoflight Sine Sweep Test Levels for LIS Instrument

Axis	Frequency (Hz)	Level
X	5.0 - 6.85 6.85 - 50.0	0.5" D.A. ± 1.2 g
Y	5.0 - 7.0 7.0 - 33.0 33.0 - 50.0	0.5" D.A. ± 1.25 g ± 0.5 g
Z	5.0 - 6.25 6.25 - 33.0 33.0 - 50.0	0.5" D.A. ± 1.0 g ± 0.5 g

Note: 1. Sweep rate 4 octaves per minute.

2. If required, the above levels should be notched for acceptance units to not exceed the design limit load, and for protoflight units to not exceed 1.25 times the design limit load.

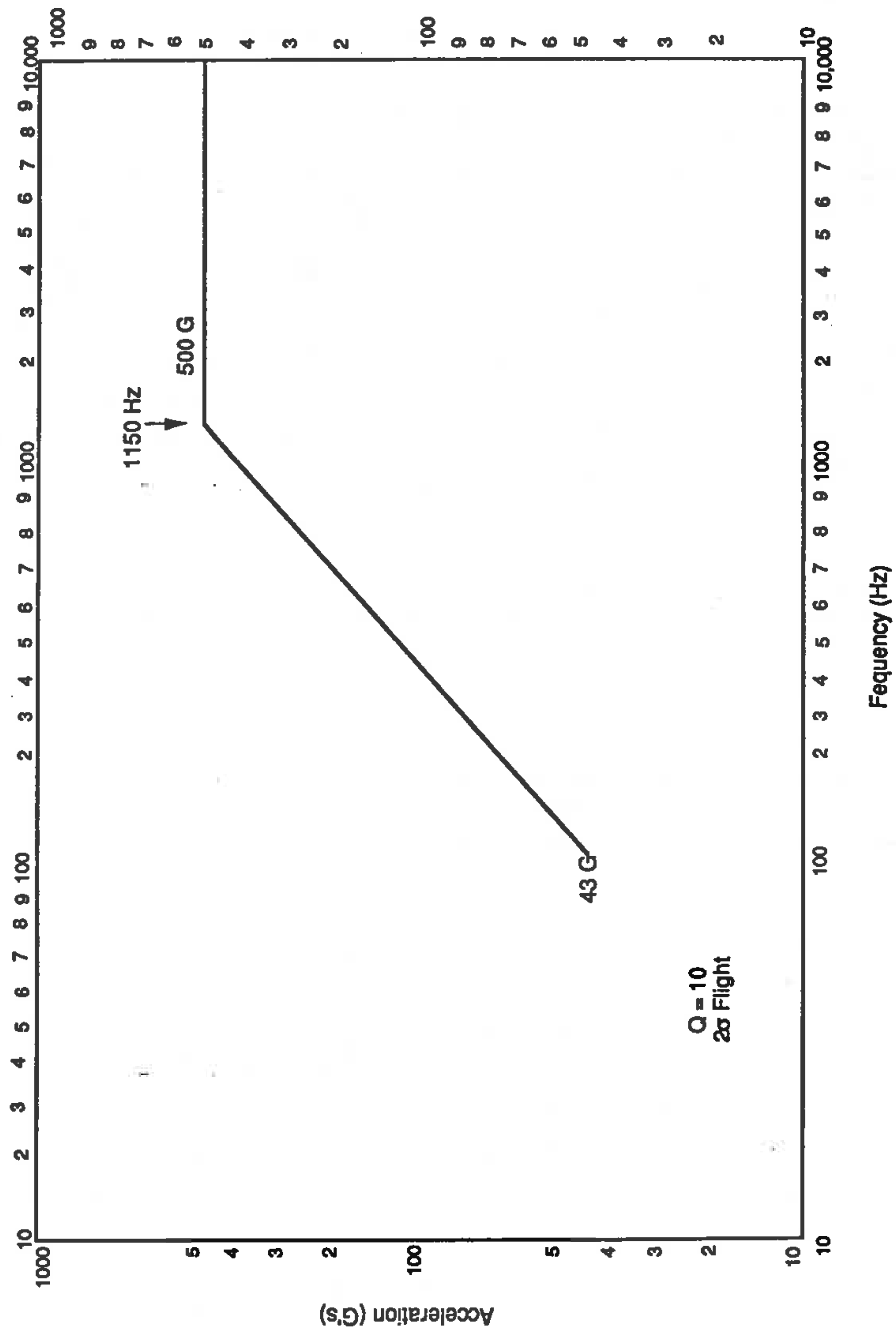


Figure 3.2–9
Estimated Shock Environment

4. THERMAL INTERFACE REQUIREMENTS

The TRMM spacecraft shall not be used as a heat source or sink. Worst case conductive and radiative heat transfer between the TRMM spacecraft and the LIS instrument is defined in the following paragraphs. These values envelope the expected results and can be used by MSFC for worst case thermal analysis.

MSFC shall supply a Reduced Geometric Math Model (RGMM) and a Reduced Thermal Math Model (RTMM) to GSFC. GSFC shall incorporate these models into the all-up observatory models and perform thermal analyses as necessary to verify and revise the LIS thermal environment outlined in this document.

The results presented in the following sections are based on the LIS instrument configuration illustrated in Figures 4.0–1 and 4.0–2 and documented in the Thermal Interface Control Drawing.

4.1 HEAT TRANSFER

4.1.1 Conduction

The maximum heat transfer across the LIS mount interface shall not exceed 5 Watts. For design purposes, the TRMM baseplate temperature should be treated as a boundary. The cold and hot case boundary temperatures are specified in 4.1.1.1.

4.1.1.1 Temperature at spacecraft side of the LIS Instrument Interface

	COLD	HOT
• Pre-Launch (Post Encapsulation):	15	25°C (30 - 60% Rh)
• Launch :	TBD°C	
• On-Orbit		
– Engineering Mode :	-10	50°C
– Low Power Mode :	-10	50°C
– Mission Mode :	-10	40°C
– Safe Hold Mode :	-10	50°C

4.1.2 Radiation Heat Exchange

4.1.2.1 General

Incident radiation between the spacecraft and the instrument on any given surface shall not exceed 480 W/M^2.

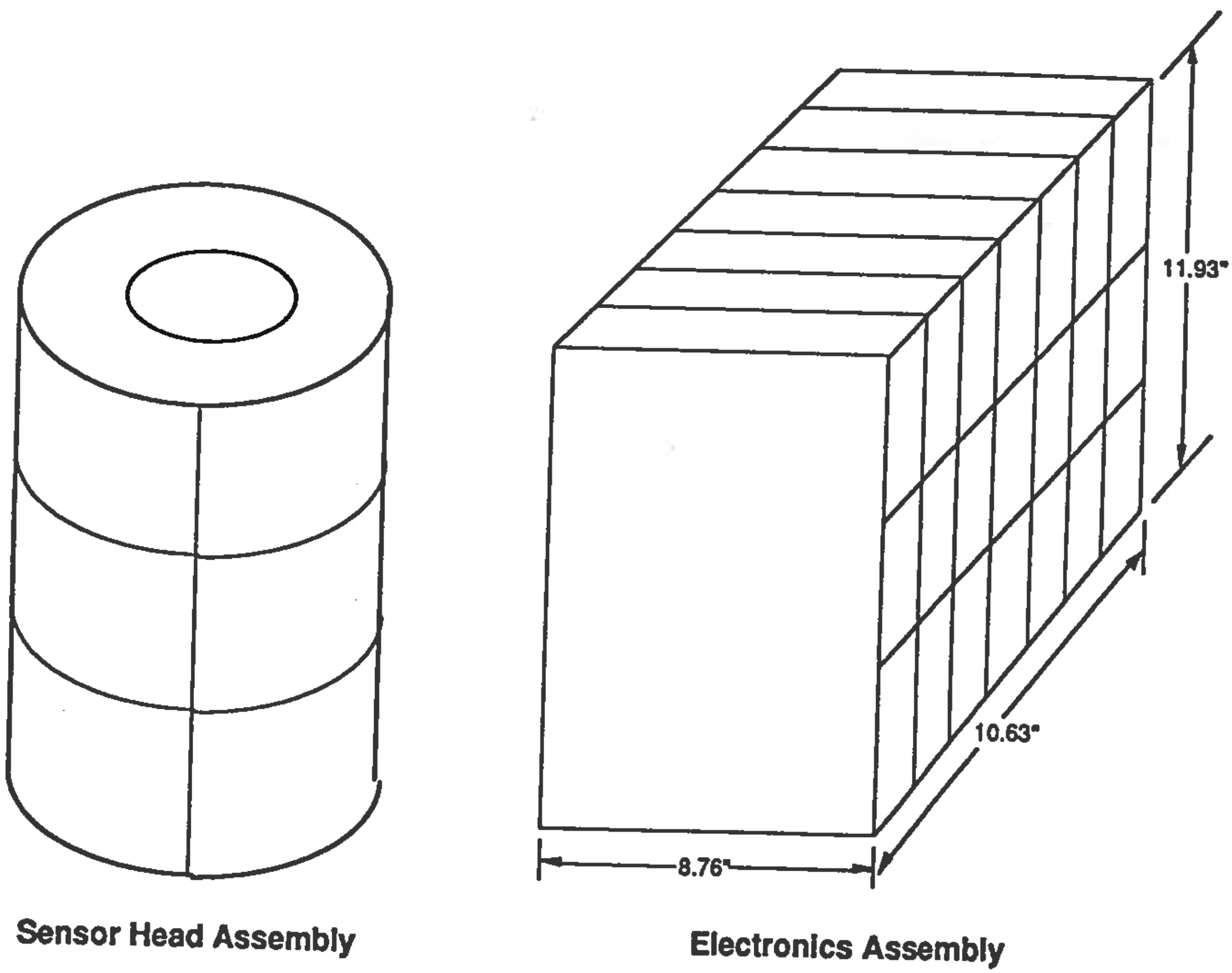


Figure 4.0–1
LIS Instrument Thermal Configuration

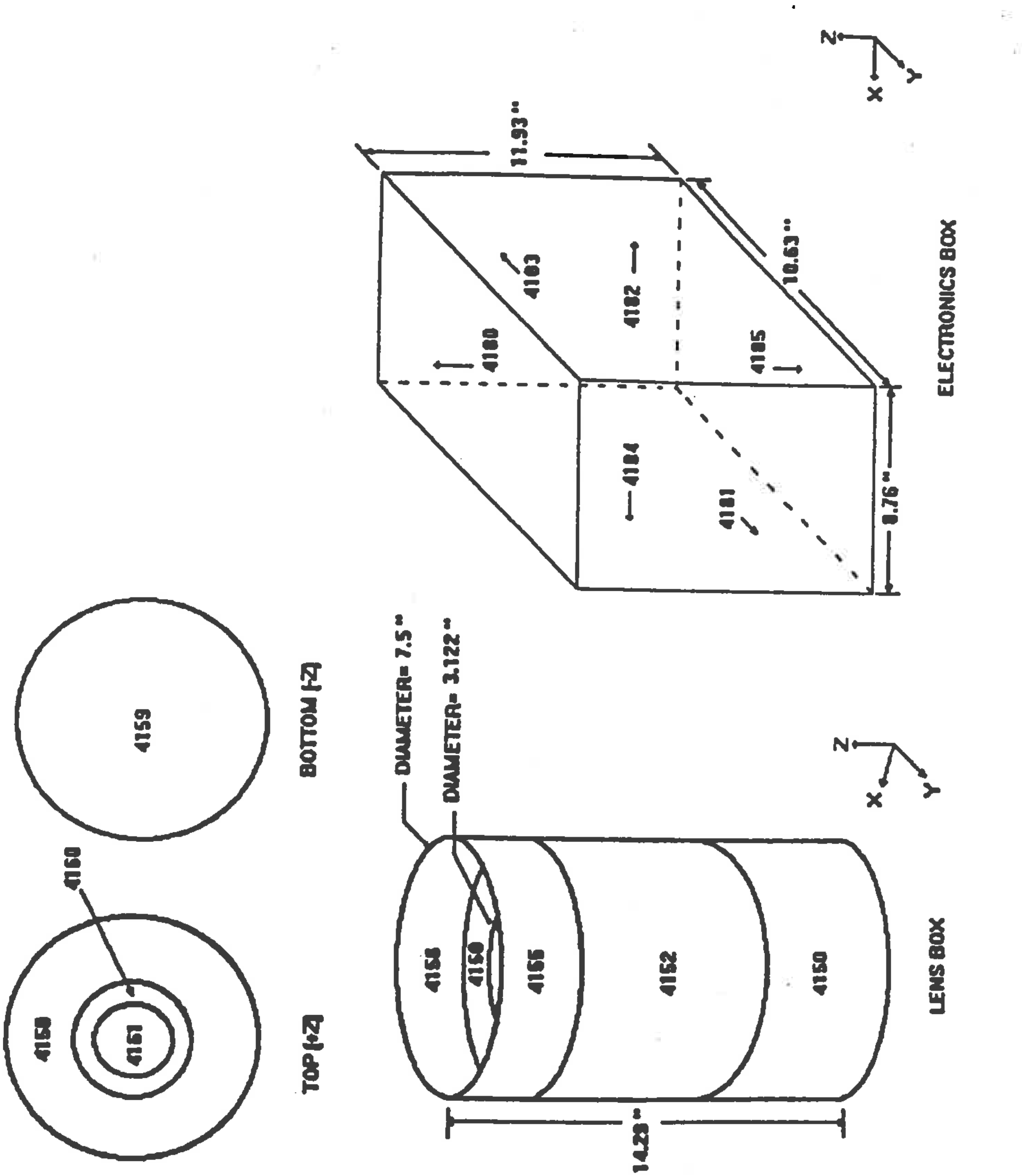


Figure 4.0–2
LIS Instrument Thermal Nodal Model

4.1.2.2 On-Orbit

Table 4.1–1 shows the TRMM spacecraft to LIS instrument radiation heat exchange. These values are based on the LIS instrument thermal configuration in Figure 4.0–1 and the optical properties presented in Table 4.1–2. Net energy values presented in Table 4.1–1 are based on the following equation:

$$q_{net\ i} = \sigma \Sigma \mathcal{F}_i \left(T_i^4 - T_{s/c}^4 \right)$$

σ = Stefan-Boltzmann constant

$\Sigma \mathcal{F}_i$ = sum of Script Fs from instrument surface i to spacecraft, includes spacecraft and instrument emissivities and view factors.

T_i = temperature of instrument surface i

$T_{s/c}$ = temperature of spacecraft that instrument surface i views

Table 4.1-1
LIS Instrument/Spacecraft Radiation Heat Exchange

5/16/94

RTMM Surface & Description	Σ 𝓕 to Spacecraft Hot/Cold	Energy from Spacecraft[1] W/Sq-M	
		Max.	Min.
4150 LISLB RADIATOR +Y/-X	0.145/0.147	61	15
4152 LISLB RADIATOR +Y/-X	0.070/0.072	30	7
4154 LISLB RADIATOR +Y/-X	0.063/0.065	27	6
4156 LISLB RADIATOR +Y/-X	0.031/0.031	13	3
4158 LISLB INTERNAL SURFACE -Y/+X	0.000/0.000	0	0
4160 LISLB RADIATOR +Z	0.000/0.000	0	0
4162 LISLB +Z LENS BARREL	0.000/0.000	0	0
4163 LISLB +Z OPTICAL GLASS	0.000/0.000	0	0
4167 LISLB MLI -Y/+X	0.315/0.316	133	31
4180 LISEB RADIATOR +Z	0.019/0.019	8	2
4190 LISEB MLI +Y	0.146/0.147	62	15
4182 LISEB RADIATOR -X	0.120/0.120	51	12
4191 LISEB MLI -Y	0.477/0.477	202	47
4192 LISEB MLI +X	0.421/0.421	178	42

NOTE: 1) Heat exchange values are based on optical properties as listed in Table 4.1-2 for UV absorptance and for emittance.

2) $Q_{energy\ from\ spacecraft} = \sigma \Sigma \mathcal{F}_i T_{s/c}^4$

σ = Stefan-Boltzmann constant

$\Sigma \mathcal{F}_i$ = sum of Script Fs from instrument surface i to spacecraft, includes spacecraft and instrument emissivities and view factors.

$T_{s/c}$ = temperature of spacecraft

Table 4.1-2
Instrument Surface Optical Properties

5/6/94

RGMM Surface & Description	UV Absorptance		Emittance	
	BOL	EOL	BOL	EOL
4150 LISLB RADIATOR +Y/-X	.14	.30	.90	.90
4151 LISLB MLI -Y/+X	.22	.60	.89	.89
4152 LISLB RADIATOR +Y/-X	.14	.30	.90	.90
4153 LISLB MLI -Y/+X	.22	.60	.89	.89
4154 LISLB RADIATOR +Y/-X	.14	.30	.90	.90
4155 LISLB RADIATOR -Y/+X	.22	.60	.89	.89
4156 LISLB INTERNAL +Y/-X	.97	.96	.90	.90
4157 LISLB RADIATOR +Y/-X	.14	.30	.90	.90
4158 LISLB INTERNAL -Y/+X	.97	.96	.90	.90
4159 LISLB MLI -Y/+X	.22	.60	.89	.89
4160 LISLB +Z NADIR	.97	.96	.90	.90
4161 LISLB -Z (BLOCKER SURFACE)	.99	.99	.99	.99
4162 LISLB +Z LENS BARREL	.34	.34	.05	.05
4163 LISLB +Z OPTICAL GLASS	1.00	1.00	1.00	1.00
4180 LISEB RADIATOR +Z, NADIR	.14	.30	.90	.90
4181 LISEB MLI +Y	.22	.60	.89	.89
4182 LISEB RADIATOR -X	.14	.30	.90	.90
4183 LISEB MLI -Y	.22	.60	.89	.89
4184 LISEB MLI +X	.22	.60	.89	.89
4185 LISEB -Z (BLOCKER SURFACE)	.99	.99	.99	.99

4.2 ABSORBED ENVIRONMENTAL FLUXES (SOLAR, ALBEDO, EARTH)

Instrument absorbed cold and hot case environmental fluxes are provided in Tables 4.2–1 and 4.2–2, respectively. Additionally, GSFC will provide transient fluxes on a High Density 3.5 inch floppy disk. MSFC shall provide to GSFC the beta angles that yield the worst hot and cold case LIS instrument temperatures for the mission nominal and safe hold attitudes. GSFC shall perform independent analysis to verify the worst hot and cold cases are at these beta angles.

4.2.1 Thermal Parameters

Thermal Flux Source	Hot	Cold
• Solar constant	1419 W/m^2	1286 W/m^2
• Albedo factor	0.35	0.25
• Earth IR	265 W/m^2	208 W/m^2

4.2.1.1 Instrument Heat Fluxes

Mission Phase	Hot	Cold
• Pre-Launch	N/A	N/A
• Launch	**TBD**	**TBD**
• On-Orbit, Nominal Attitude	Table 4.2–1	Table 4.2–2
• On-Orbit, Safe Hold Attitude	Table 4.2–1	Table 4.2–2

4.3 THERMAL ANALYSIS

4.3.1 Thermal Design Conditions

The following sections define the environmental and spacecraft conditions to be used for instrument thermal analysis.

4.3.1.1 Mission Phase (Reserved)

4.3.1.2 Pre-Launch: After Fairing Close-Out Environment

- Air Temperature : 20 ± 5°C
- Relative Humidity : 50 ± 10%
- Air Flow Rate : 100 m^3/min

4.3.1.3 Launch and Ascent

4.3.1.3.1 Prior to Fairing Jettison

Presented in Figure 4.3–1 are the temperature histories at several locations on the fairing, time of lift-off through fairing jettison. For analysis purposes a hemispherical emissivity for the fairing surfaces of 0.1 shall be used.

Table 4.2-1
On-Orbit Worst Hot Case Fluxes - W/m²

5/6/94

RTMM Surface & Description	NOMINAL MISSION ATTITUDE Beta = 0.°		SAFE-HOLD ATTITUDE Beta = 0°, Yaw = 6.5°, and Pitch = +10°	
	IR	UV	IR	UV
4150 LISLB RADIATOR +Y/-X	75	46	69	25
4152 LISLB RADIATOR +Y/-X	73	59	81	34
4154 LISLB RADIATOR +Y/-X	73	67	83	46
4156 LISLB RADIATOR +Y/-X	77	67	61	175
4158 LISLB INTERNAL SURFACE -Y/+X	81	67	36	49
4160 LISLB RADIATOR +Z	155	101	42	21
4162 LISLB +Z LENS BARREL	11	44	3	9
4163 LISLB +Z OPTICAL GLASS	224	131	61	29
4167 LISLB MLI -Y/+X	65	62	42	124
4180 LISEB RADIATOR +Z	215	49	69	56
4190 LISEB MLI +Y	57	32	41	33
4182 LISEB RADIATOR -X	76	82	75	30
4191 LISEB MLI -Y	46	33	30	39
4192 LISEB MLI +X	71	53	32	117

NOTES: 1) Absorbed flux values are based on optical properties for UV absorptance and IR emittance as listed in Table 4.1-2.

2) Absorbed flux are orbital average values.

Table 4.2-2
On-Orbit Worst Cold Case Fluxes - W/m^2

5/6/94

RTMM Surface & Description	NOMINAL MISSION ATTITUDE Beta = 58.5°		SAFE-HOLD ATTITUDE Beta = 58.5°, Yaw=16.5°, and Pitch = -10°	
	IR	UV	IR	UV
4150 LISLB RADIATOR +Y/-X	59	6	46	3
4152 LISLB RADIATOR +Y/-X	57	9	57	4
4154 LISLB RADIATOR +Y/-X	57	9	58	4
4156 LISLB RADIATOR +Y/-X	60	49	45	3
4158 LISLB INTERNAL SURFACE -Y/+X	63	29	25	3
4160 LISLB RADIATOR +Z	121	39	40	1
4162 LISLB +Z LENS BARREL	9	15	3	1
4163 LISLB +Z OPTICAL GLASS	176	45	57	1
4167 LISLB MLI -Y/+X	51	24	34	2
4180 LISEB RADIATOR +Z	169	11	61	1
4190 LISEB MLI +Y	45	7	29	2
4182 LISEB RADIATOR -X	60	13	51	3
4191 LISEB MLI -Y	36	19	24	1
4192 LISEB MLI +X	59	12	28	1

NOTES: 1) Absorbed flux values are based on optical properties for UV absorptance and IR emittance as listed in Table 4.1-2.

2) Absorbed flux are orbital average values.

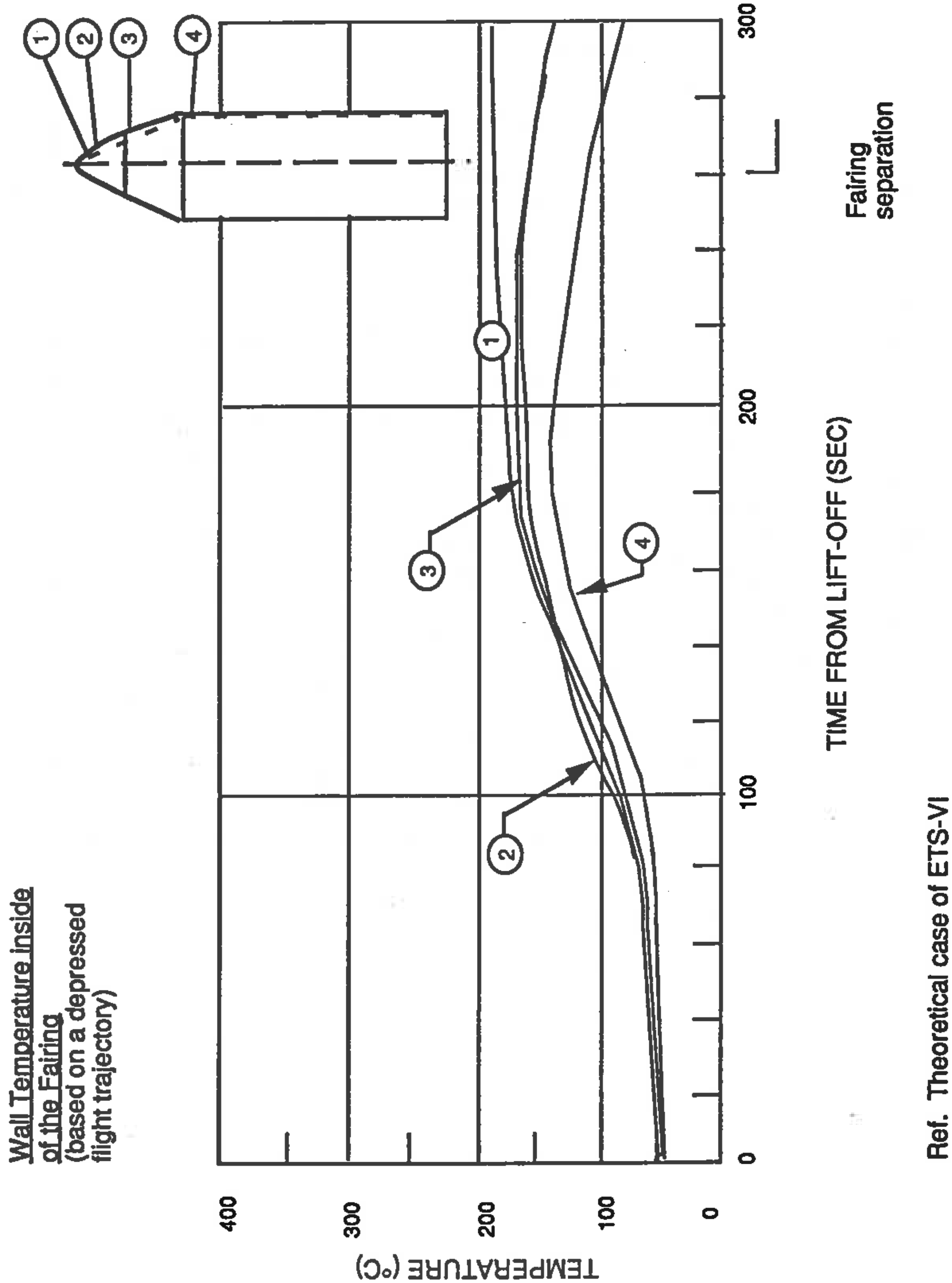


Figure 4.3–1
Fairing Jettison Wall Temperature

4.3.1.3.2 Post Fairing Jettison

The free molecular heating rate due to convective and radiative effects shall be less than 1135 W/m^2. The free molecular heating history profile is present in Figure 4.3–2.

4.3.1.4 On-Orbit, Nominal Mission Attitude

• Altitude	:	350 km
• Inclination	:	35°
• Attitude	:	Earth pointing Spacecraft +Z axis points to nadir Spacecraft +X axis coincident with velocity vector
• Sun excursion	:	Yaw maneuver performed as necessary to keep the Sun on the -Y face of the spacecraft's X-Z plane. (β = 0°±1°)
• Beta Angle[1]	:	0°<|β|<58.5° Hot: 0° Cold: 58.5°

4.3.1.5 On-Orbit, Safe Hold Attitude

• Altitude	:	350 km
• Inclination	:	35°
• Attitude	:	Solar inertial Spacecraft +X axis inertial to Sun with a +16.5° rotation about spacecraft +Z axis (with a ±10° pitch and yaw excursions from this Safe Hold reference axis).
• Beta Angle	:	Hot: 0° Cold: 58.5°

NOTE: 1) The Beta angle is defined as the angle between the solar vector (Earth-Sun line) and the local vertical (spacecraft-Earth center line) in the orbit plane when the TRMM spacecraft is closest to the Sun (orbit noon).

4.3.1.6 Environmental Constants

	Hot	Cold
• Solar constant	1419 W/m^2	1286 W/m^2
• Albedo factor	0.35	0.25
• Earth IR	265 W/m^2	208 W/m^2

TBS

Figure 4.3–2
Free Molecular History Profile

4.3.1.7 Thermal Control Heater Design

- Minimum bus voltage for analysis : 21 Vdc
- Maximum bus voltage for component derating : 35 Vdc

4.3.1.8 Multi-layer Insulation

Worst case analysis shall be performed assuming a minimum range for the effective emittance (ε^*) of 0.005 to 0.03.

Hot:	bias to give worst case
Cold:	bias to give worst case

GSFC will attach the MLI and the MLI fasteners between the TRMM spacecraft and the LIS instrument after integration of the LIS instruments at GSFC.

4.3.2 Thermal Model Requirements

The LIS instrument geometry and thermal math models identified herein are required to be delivered to GSFC in accordance with an approved schedule. The models will be incorporated into the integrated TRMM spacecraft models to be used for thermal studies and interface analyses for various conditions such as prelaunch, launch, and on-orbit operations.

A geometric math model of 30 or less external surfaces in TRASYS format (including Correspondence Data) is required. Along with the geometric math model, a thermal math model of 30 nodes or less is required in SINDA format. The models must be delivered on a 3.5" micro floppy disk: 2DD and ASCII format using MS-DOS.

4.3.2.1 Thermal Model Criteria

a. The thermal models should be reduced versions (RGMM and RTMM) of MSFC's detailed models; it is a goal that all critical nodes should correlate to within 2°C. A comparison between the reduced and detailed models steady-state outputs is required for both nominal mission and safehold mode.

b. Nodes shall represent 100 percent of external surface area.

c. Separate nodes shall be provided for all external surface areas including external layers of insulation blankets and spacecraft mounting points.

d. Nodes shall represent localized power dissipation.

e. Individual node summation shall represent total mass within 10 percent.

4.3.2.2 Thermal Model Data Requirements

MSFC is to provide a report describing the LIS instrument thermal design and math models. This report shall be submitted only as part of the first thermal model delivery package. Included in this report shall be the following:

a. Provide the following temperature limits:

- Temperature limits necessary for adequate operational performance.
- Temperature limits for which catastrophic failure occurs.
- Temperature limits for non-operational shipment or storage.

b. Provide the following temperature gradient limits:

- The temperature gradient constraints required for the spacecraft-mounting (conductive sink) surfaces and the rationale for the requirements.
- The temperature gradient constraints required between identified spacecraft radiative surfaces (radiative sink) and the rationale for the requirements.

c. Provide the following power dissipation information:

- An accurate definition of the power required and the power dissipated as heat in the parts and/or electronics subassemblies is required for the following conditions:
  - Operating flight steady-state conditions.
  - Non-operating flight steady-state heater dissipation at +21 Vdc.
  - Maximum transient (peak) flight operating power duration and frequency.
- The location of the dissipated power (as heat) is to be identified to its corresponding part and/or electronics subassembly level and is to be related to the analytical model node number(s).
- The power, control bank (ON/OFF) and the location (related to analytical model node number) are required for any thermal control heaters that are placed to maintain required temperatures.

d. Provide the following mechanical properties:

- The LIS instrument assembly weight, size, and volume must be given with the relevant uncertainties. An Interface Control Drawing should be presented giving external dimensions for reference to indicate the size and volume. The analytical model node numbers should be located on the sketch for reference. In addition, the surface area, materials, and coatings of each node in the models must be listed.

e. Provide the surface finishes and optical properties data:

- LIS instrument materials and surface finishes, with related total hemispherical emittance and UV absorptance should be identified for the analytical model surfaces/nodes.

f. Miscellaneous:

- Any other important thermal data required to use or understand the analytical thermal model should be provided.

5. MODES OF OPERATION

This section provides an overview of the modes of operation for the TRMM observatory and the LIS instrument.

5.1 OBSERVATORY MODES

There are eight modes of operation for the TRMM observatory. The modes of operation are as follows:

a. Launch Mode

b. Initial Orbit Acquisition Mode

c. Engineering Mode

d. Instrument Test and Calibration Mode

e. Mission Mode (including yaw maneuver)

f. Low Power Mode

g. Safe Hold Mode

h. Deep Space Network/Ground Network Mode

Table 5.1–1 describes the modes of operation for the TRMM observatory and the LIS instrument. This table addresses the following:

a. Observatory mode

b. Mode entry requirements

c. Mode exit requirements

d. Telemetry link interfaces (data group, mode, data rate)

e. Command link interfaces (data rate)

f. Antenna/network usage

g. Observatory power bus status

h. Observatory configuration (control, orientation)

i. Observatory attitude

j. LIS instrument mode

k. LIS instrument configuration

Table 5.1–1
Modes of Operation Summary

Observatory Mode	Mode Entrance	Mode Exit	Telemetry Link	Command Link	Antenna/ Network	Power Bus Status	Observatory Configuration	LIS Mode	LIS Configuration
Launch	On ground	Observatory Separation	DG 1 Mode 2 1.0 kbps Q-Channel (R/T)	500 bps	Omni TDRSS	Non-essential: OFF Essential: ON Survival Heaters Enabled	Stowed	Off	Instrument OFF
Initial Orbit Acquisition (Phase 1)	Command or autonomous	Command or autonomous to safe hold/ low power	DG 1 Mode 2 1.0 kbps Q-Channel (R/T)	500 bps	Omni TDRSS	Non-essential: OFF Essential :ON Survival Heaters Enabled	Initial Deployment	Off	Instrument OFF
Initial Orbit Acquisition (Phase 2)	Command	Command or autonomous to safe hold/ low power	DG 1 Mode 1 1.0 kbps Q-Channel (R/T)	500 bps	Omni TDRSS	Non-essential: ON Essential: ON Survival Heaters Enabled	Initial Deployment	Off	Instrument OFF
Engineering	Command	Command or autonomous to safe hold/ low power	DG 1 Mode 3 32 kbps I-Channel (R/T) 2.048 Mbps Q-Channel (P/B and R/T)	1 kbps	HGA TDRSS	Non-essential : ON Essential: ON Survival Heaters Enabled	Normal spacecraft operations No science	Mission (day/night)	Instrument ON; Science data gathering
Instrument Calibration & Test (PR Test)	Command	Command or autonomous to safe hold/low power	DG 1 Mode 3 32 kbps I-Channel (R/T) 2.048 Mbps Q-Channel (P/B)	1 kbps	HGA TDRSS	Non-essential: ON Essential: ON Survival Heaters Enabled	Normal spacecraft operations 90° yaw-maneuvered Science gathering mode	Mission (day/night)	Science data gathering
Instrument Calibration & Test (CERES Deep Space Calibration Maneuver)	Command	Command or autonomous to safe hold/ low power	DG 1 Mode 3 32 kbps I-Channel (R/T) 2.048 Mbps Q-Channel (P/B)	1 kbps	HGA TDRSS	Non-essential: ON Essential: ON Survival Heaters Enabled	Spacecraft inertial attitude Science gathering mode	Off	Instrument OFF

The following sections provide a summary of each of the modes. More detailed definitions of each mode are found in the TRMM System Specification : Space Segment (TRMM–490–002) and the TRMM Observatory Low Power Mode/Safe Hold Mode Architecture and Process Description Document (TRMM–490–082).

5.1.1 Launch Mode

This is the initial mode of the TRMM observatory from launch to separation from the H-II expendable launch vehicle (ELV). The TRMM observatory is in a stowed position with the non-essential power bus off and the essential power bus on. This provides for operation of the survival heaters through ascent and orbit insertion.

5.1.2 Initial Orbit Acquisition Mode

The transition from Launch Mode to the Initial Orbit Acquisition Mode is initiated automatically by the TRMM observatory at the time of separation from the H-II ELV. During this mode, the following will occur:

a. Deployment of the solar arrays

b. Deployment of the high gain antenna (HGA)

c. Initiation of communications using the omnidirectional low gain antennas (LGAs)

d. Acquisition of mission attitude (rate null, Earth acquisition, yaw acquisition)

No instrument operations will occur during this mode of operation.

5.1.3 Engineering Mode

The Engineering Mode is initiated by the TRMM observatory upon receipt of ground commands after Earth capture and normal mission attitude has been accomplished. The Engineering Mode can also be entered, via ground commands, from the Mission Mode. This mode will be used exclusively for extensive evaluation of the condition of the TRMM observatory. This mode will be used as part of the early on-orbit checkout of the TRMM observatory and can be used at any time throughout the mission.

Although individual instruments may be powered, no science data collection activities will occur during this mode.

During this mode, the TRMM observatory will use the HGA via the Tracking and Data Relay Satellite System (TDRSS) for communications.

The TRMM observatory will remain in this mode until either:

a. Detection of a fault requiring transition to either Low Power Mode or Safe Hold Mode; or

b. Receipt of ground commands to commence exiting this mode.

Table 5.1–1
Modes of Operation Summary (continued)

Observatory Mode	Mode Entrance	Mode Exit	Telemetry Link	Command Link	Antenna/ Network	Power Bus Status	Observatory Configuration	LIS Mode	LIS Configuration
Mission	Command	Command or autonomous to safe hold/ low power	DG 1 Mode 3 32 kbps I-Channel (R/T) 2.048 Mbps Q-Channel (P/B)	1 kbps	HGA TDRSS	Non-essential: ON Essential: ON Survival Heaters Enabled	Normal spacecraft operations Science gathering mode	Mission (day/night)	Instrument ON Normal operations Science data gathering
Yaw Maneuver (every 2-4 weeks)	Command Ancillary Data will flag initiation and completion of maneuver	Command Ancillary Data will flag initiation and completion of maneuver	DG 1 Mode 3 32 kbps I-Channel (R/T) 2.048 Mbps Q-Channel (P/B)	1 kbps	HGA TDRSS	Non-essential: ON Essential: ON Survival Heaters Enabled	Normal spacecraft operations Science gathering mode	Mission (day/night)	Instrument On Science data gathering
Safe Hold	Command or autonomous	Command	DG 1 Mode 2 (Phase 1) DG 1 Mode 1 (Phase 2) 1.0 kbps Q-channel (R/T)	500 bps	Omni TDRSS	Non-essential: OFF Essential: ON Survival Heaters Enabled	Thermally and power safe conditions Orientation (see Figure 5.5-2)	OFF	Instrument OFF
Low Power	Command or autonomous	Command or autonomous to safe hold	DG 1 Mode 3 32 kbps I-Channel (R/T) 2.048 Mbps Q-Channel (P/B)	1 Kbps	HGA TDRSS	Non-essential: OFF Essential: ON Survival Heaters Enabled	Power safe condition Normal spacecraft orientation ACS control	OFF	Instrument OFF
DSN/GN	Command	Command	1.024 Mbps (R/T and P/B interleaved)	2 kbps	Omni DSN/GN	Non-essential: OFF Essential: ON Survival Heaters Enabled	Deployment	OFF	Instrument OFF

5.1.4 Instrument Test and Calibration Mode

The Instrument Test and Calibration Mode is used by the TRMM observatory for either of the following:

a. Provide for the PR instrument antenna pattern test

b. Provide the CERES instrument a view of deep space for in-orbit calibration (CERES Deep Space Calibration Maneuver).

This mode is initiated by ground commands and uses the HGA via TDRSS for communication.

During this mode, when conducting the PR instrument antenna test, the TRMM observatory will be in either a normal attitude or a 90 degree yaw-maneuvered attitude. During this mode, when conducting the CERES Deep Space Calibration Maneuver, the TRMM observatory will be placed in an inertially fixed attitude, as shown in Figure 5.1–1.

The TRMM observatory will remain in this mode until either:

a. Detection of a fault requiring transition to either Low Power Mode or Safe Hold Mode; or

b. Receipt of ground commands to commence exiting this mode.

5.1.5 Mission Mode

The Mission Mode is the normal science data gathering mode for the TRMM observatory. This mode is initiated by ground commands and uses the HGA communication link via TDRSS. During this mode, the TRMM observatory will be in a nadir pointing orientation. Approximately every 2 to 4 weeks the TRMM Observatory shall perform a 180° spacecraft yaw maneuver when the beta angle is 0°±1° (Sun aligned with the orbit plane). Time between maneuvers will be based on the TRMM orbit, in which the beta angle will vary with time between -58.5° and +58.5°. The ancillary data packet will contain a flag that will indicate the initiation and the completion of the yaw maneuver.

The TRMM observatory will remain in this mode until either:

a. Detection of a fault requiring transition to either Low Power Mode or Safe Hold Mode; or

b. Receipt of ground commands to commence exiting this mode.

5.1.6 Low Power Mode

The Low Power Mode is a failure mode which is entered either:

a. Automatically by the TRMM observatory upon detection of an anomalous power system condition; or

b. Receipt of ground commands.

During this mode, the TRMM observatory will be in a low power safe state with power removed from the non-essential power bus. The TRMM observatory will send a "warning signal" to the instruments and pre-selected subsystems, wait a minimum of 90 seconds, and then remove power. (Figure 7.4–1 shows the interface circuitry and signal characteristics.) While in this mode the TRMM observatory shall maintain survival heater power.

The "warning signal" is not utilized by the LIS instrument.

During this mode, the TRMM observatory shall cease all onboard science operations. The TRMM observatory will remain in a nominal nadir pointing attitude with the attitude control system (ACS) maintaining full control of the TRMM observatory.

During this mode, the TRMM observatory will use the HGA for ground communication.

The TRMM observatory will remain in this mode until either:

a. Detection of a fault requiring transition to Safe Hold Mode; or

b. Receipt of ground commands to commence exiting this mode.

5.1.7 Safe Hold Mode

This mode is a failure mode which is initiated either:

a. Automatically by the TRMM observatory upon detection of anomalous attitude control conditions; or

b. Receipt of ground commands.

During this mode, the TRMM observatory shall be placed in a stable attitude that is both temperature and power safe and that will allow a full recovery to normal mission operations. Specifically, the TRMM Observatory will be oriented with the sun line at 16.5° from the X-axis (velocity vector). The solar arrays will be rotated to and maintained at an indexed position with the sun line 10° off the solar array normal. During Safe Hold Mode the TRMM spacecraft is orientated so that the sun line lies in the +X, -Y quadrant of the plane formed by the spacecraft x-axis and the solar array normal (the X-Y plane when the solar array is in its index position). The X-axis is 16.5° from the sun line while the solar array normal is 10° from the sun line. There is no preferred orientation of the spacecraft about the sun line, i.e. the spacecraft can be rotated at any angle about the sun line as long as the sun line is maintained in the X-Y plane and the angles of the sun line with respect to the X-axis and solar array are preserved. (Figure 5.1–2 shows the TRMM observatory Safe Hold Mode orientation.)

Power will be removed from the TRMM observatory non-essential power bus. The TRMM observatory will send a "warning signal" to the instruments and pre-selected subsystems, wait a minimum of 90 seconds, and then remove power. (Figure 7.4–1 shows the interface circuitry and signal characteristics.) Throughout this mode the TRMM observatory shall maintain survival heater power.

The "warning signal" is not utilized by the LIS instrument.

During this mode, the TRMM observatory shall cease all onboard science operations.

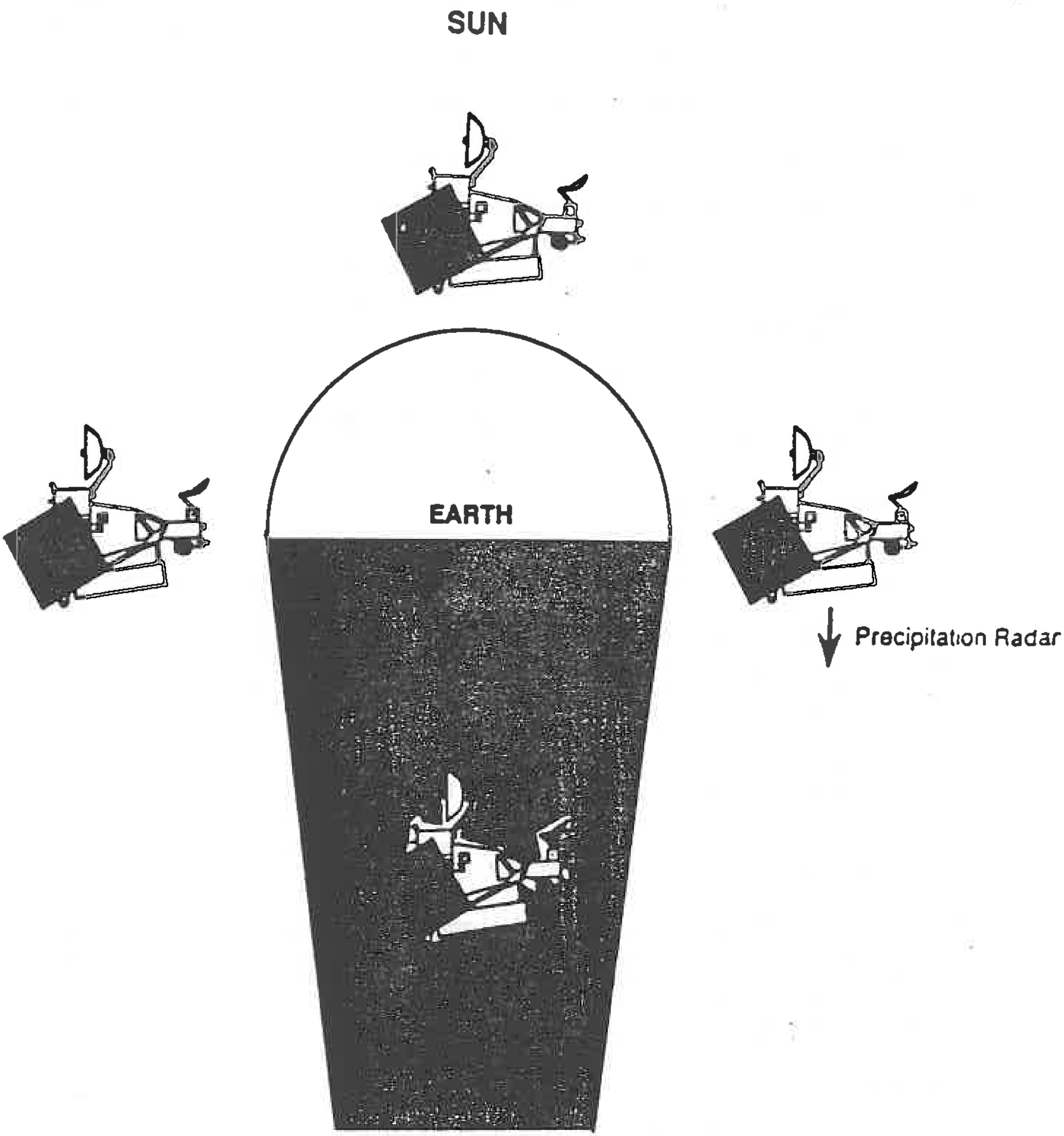


Figure 5.1–1
TRMM Observatory/CERES Instrument
Test and Calibration Mode Orientation

During this mode, the TRMM observatory will use the the omnidirectional LGAs for ground communications.

The TRMM observatory will remain in this mode until receipt of ground commands to exit.

5.1.8 Deep Space Network/Ground Network Mode

The Deep Space Network/Ground Network (DSN/GN) Mode is a backup mode which will be used if attempts to establish communications via TDRSS are unsuccessful during the Initial Orbit Acquisition Mode. The TRMM observatory will transition to this mode only upon receipt of ground commands. During this mode, the TRMM observatory will communicate through the omni directional LGAs using the transponder GSTDN mode of operation.

Since this mode is used while the TRMM observatory is in Initial Orbit Acquisition Mode, the instruments are not powered; thus resulting in no acquisition of science data.

The TRMM observatory shall remain in this mode until receipt of ground commands to exit.

5.2 LIS INSTRUMENT OPERATIONAL MODES

LIS instrument modes:

a. Off Mode: The LIS instrument shall be unpowered and in its safe state configuration. During this mode survival heater power will be on.

b. Mission Mode (day/night): The LIS instrument has only one mission mode of operation. During this mode, science data packets will always be sent.

The LIS instrument has several sub-modes of the Mission Mode which are listed in Table 5.2–1. These sub-modes of operation are transparent to the TRMM spacecraft.

The LIS instrument shall be provided with means to command it into its various sub-modes of operation. A command list shall also be provided for approval by the GSFC (see Section 8.0).

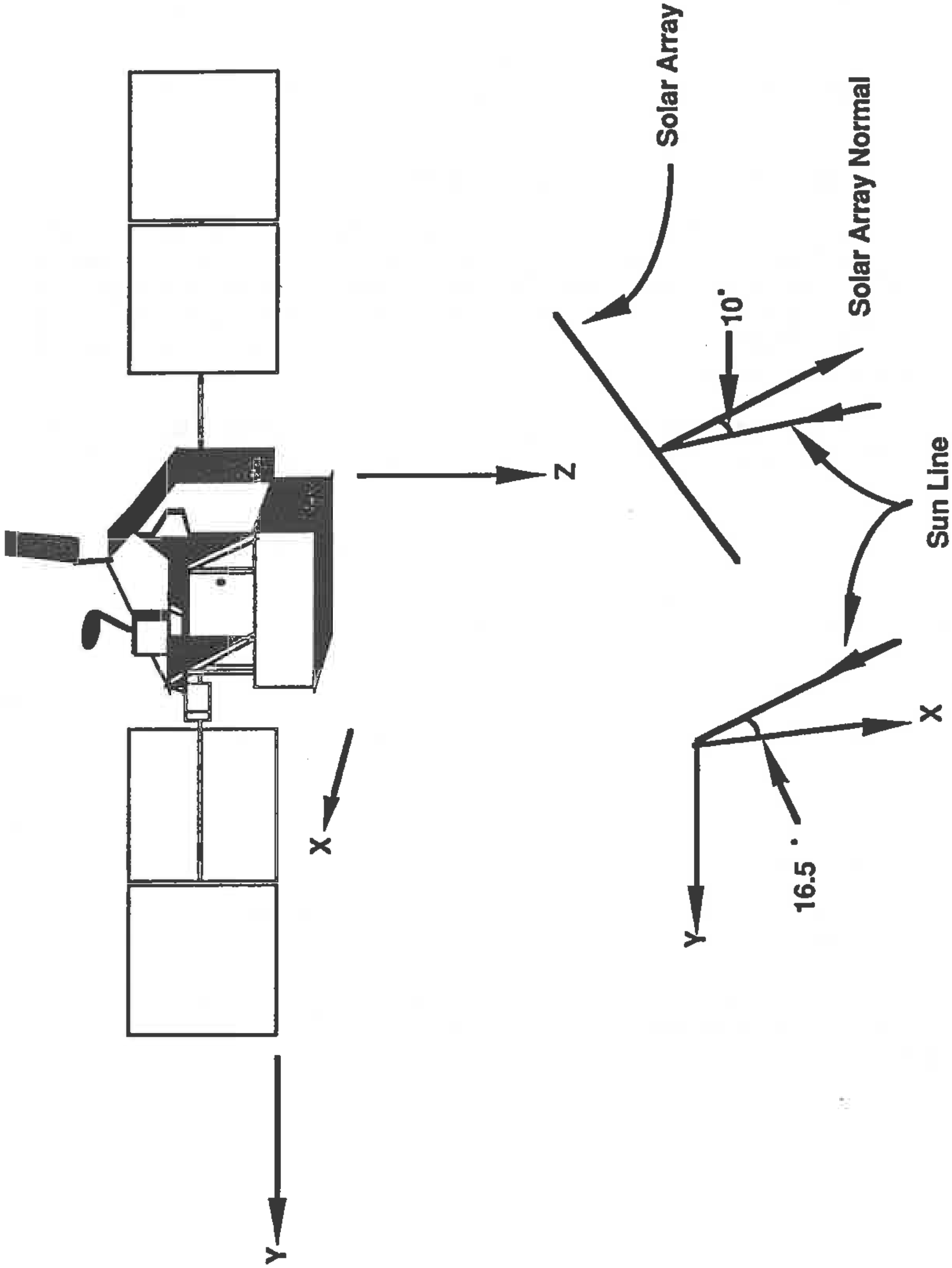


Figure 5.1–2
TRMM Observatory Safe Hold Mode Orientation

Table 5.2–1
LIS Instrument Mission Sub-Modes

2/12/93

Name	Description
BACKGROUND SEND MODE ON	This command will cause the flight software to enter the Background Send On Mode. Background data will be placed into the science data packet when space is available. Science packets will always be 512 words (1024 octets).
BACKGROUND SEND MODE OFF	This command will cause the flight software to enter the Background Send Off Mode. Background data will not be placed into the science packet. Packets will be of variable length. Minimum packet size will be 32 words (64 octets).
THRESHOLD ADJUSTMENT	This command will include 16 threshold values (packed into eight words). Upon receipt of this command the flight software will upload the new values to the RTEP threshold memory. The flight software will then read the uploaded values from the RTEP to verify upload and set the appropriate status bits.
RESET HEATERS	Upon receipt of this command the flight software will send a Reset Heaters command to the Heater Controller.
SELF TEST ENABLE	This command will cause the flight software to enter the Self Test Mode. This flight software will initiate the sending of three pulses to an optical transmitter located in the Sensor Head Assembly. After three pulses have been sent the flight software will take itself out of Self Test Mode. Science data will be gathered as during normal operations. The flight software will set the appropriated status bits to indicate which packets contain Self Test data.
HEATER SELECT MODE 2	This command wil cause the flight software to monitor the filter heater temperature and test the measurement against defined upper and lower limits. If the Primary heater is active and the measurement is out of the defined limits, the flight software will issue commands to the Heater Controller to disable the Primary heater and activate the Secondary heater, and set the appropriate status bits. If the Secondary Heater is active and the measurement is out of the defined limits, the flight software will issue the command to the Heater Controller to disable the Secondary Heater and set the Both Heaters Failed Flag staus bit.
HEATER AUTO SELECT MODE 1	This command will cause the flight software to monitor the filter heater temperature and test only against an upper extreme limit. Heater switching and failure notification are the same as listed for HEATER AUTO SELECT MODE 2.
WATCHDOG ENABLE	This command will cause the flight software to enable the Watchdog Timer.
WATCHDOG DISABLE	This command will cause the flight software to disable the Watchdog Timer.

Table 5.2–1 (continued)
LIS Instrument Mission Sub-Modes

8/7/95

Name	Description
PRIMARY HEATER ON	This command will cause the flight software to send the Reset Heaters command followed by the enable Primary Heater command to the Heater Controller.
SECONDARY HEATER ON	This command will cause the flight software to send the Reset Heaters command followed by the enable Secondary Heater command to the Heater Controller.
HEATER AUTO SELECT DISABLE	This command will cause the MPR/C to stop monitoring the heater filter temperatures. The MPR/C will be unable to switch heaters. All heater control must be initiated by ground command.
GENERATE WATCHDOG TIMEOUT	This command sends the software into a section of code that does not allow it to return to the Main Loop. After 1.5 seconds the Watchdog (if enabled) will timeout and reset the MPR/C. If the Watchdog is not enabled a system reset will be required to reset the MPR/C.
TURN BOTH HEATERS ON	This command will cause the flight software to send a command to turn the Primary Heater on followed by a command to turn the Secondary Heater on. When both heaters are on the software will monitor only the Primary Heater temperature and will turn both heaters off if this value exceeds the set limit(s).
FLUSH FIFO (not used with OTD)	This command will cause the software to issue a command to RTEP digital board to reset the FIFO and FIFO count. The software will also clear all events in the event data stack.
SELECT SPACECRAFT CLOCK A	Upon receipt of this ground command the flight software will send a command to the flight hardware which will select the A Channel 1 Hz signal as the source for the Timemark Interrupt. The software will set the 1 Hz Clock Status Bits to a value of 01.
SELECT SPACECRAFT CLOCK B	Upon receipt of this ground command the flight software will send a command to the flight hardware which will select the B Channel 1 Hz signal as the source for the Timemark Interrupt. The software will set the 1 Hz Clock Status Bits to a value of 10.
SELECT SPACECRAFT CLOCK A "OR" B Power-up Configuration	Upon receipt of this ground command the flight software will send a command to the flight hardware which will select both 1 Hz signals OR'd together as the source for the Timemark Interrupt. The software will set the 1 Hz Clock Status Bits to a value of 11.

6. ENVIRONMENTAL REQUIREMENTS

6.1 PERFORMANCE

The TRMM spacecraft and the LIS instrument shall satisfy all operational requirements under the natural environment conditions for the mission orbit semi-major axis of 6728 ±1.25 km (nominally 350 km altitude).

The TRMM spacecraft and the LIS instrument shall satisfy all operational requirements under induced operating environment conditions.

6.2 PRESSURE

The LIS instrument shall operate within specification at atmospheric pressure, during instrument thermal vacuum testing, during spacecraft thermal vacuum testing and while exposed to a hard vacuum commensurate with the orbital altitude of 350 km. The design and implementation of the LIS instrument shall ensure that no corona or arcing will occur when critical pressure conditions exist while the LIS instrument is on and operating. The LIS instrument shall not be operated during the transition from sea level to operating orbit.

6.3 RADIATION

The TRMM spacecraft and the LIS instrument shall be designed to operate nominally for the minimum mission life of three years plus sixty days when subjected to the combined worst case total radiation dose values shown in Tables 6.3–1 and 6.3–2. TRMM design margins shall be 10 times the values shown in these tables.

6.4 ATOMIC OXYGEN

The TRMM spacecraft and the LIS instrument shall satisfy all operational requirements during 3.5 years of exposure to an atomic oxygen environment typical of a 350 km (±10 km) orbit for 3.5 years. Assuming a launch date of August 1997, the atomic oxygen fluence for the TRMM spacecraft and the LIS instrument surfaces in the velocity vector is 8.9×10^{22} atoms of atomic oxygen per cm^2 calculated using 2 sigma value of Schatten Predicted Solar Data.

Materials used in the construction of or applied to the TRMM spacecraft and the LIS instrument shall not generate contamination products resulting from the interaction with an atomic oxygen environment.

6.5 METEOROIDS

The TRMM spacecraft and the LIS instrument shall consider the potential problems related with the collision with meteoroids while in orbit.

Table 6.3–1
Total Dose at Center of Aluminum Spheres
(3 Years at Solar Minimum Conditions)

Z(Mils)	Z(mm)	Z(g/cm²)	Trpd. Elec.	Bremsstr.	EL+BR	Trpd Proton	EL+BR+TRP condition only	
1.46E+00	3.70E-02	1.00E-02	2.85E+04	1.06E+01	2.85E+04	2.96E+02	2.88E+04	2.88E+04
2.92E+00	7.40E-02	2.00E-02	1.56E+04	7.25E+00	1.56E+04	2.47E+02	1.58E+04	1.58E+04
4.37E+00	1.11E-01	3.00E-02	9.17E+03	5.40E+00	9.17E+03	2.22E+02	9.39E+03	9.39E+03
5.83E+00	1.48E-01	4.00E-02	5.88E+03	4.28E+00	5.88E+03	2.05E+02	6.09E+03	6.09E+03
7.29E+00	1.85E-01	5.00E-02	4.07E+03	3.55E+00	4.07E+03	1.94E+02	4.27E+03	4.27E+03
8.75E+00	2.22E-01	6.00E-02	2.99E+03	3.00E+00	2.99E+03	1.86E+02	3.18E+03	3.18E+03
1.02E+01	2.59E-01	7.00E-02	2.29E+03	2.58E+00	2.29E+03	1.78E+02	2.47E+03	2.47E+03
1.17E+01	2.96E-01	8.00E-02	1.80E+03	2.25E+00	1.81E+03	1.73E+02	1.98E+03	1.98E+03
1.31E+01	3.33E-01	9.00E-02	1.45E+03	1.99E+00	1.45E+03	1.68E+02	1.62E+03	1.62E+03
1.46E+01	3.70E-01	1.00E-01	1.17E+03	1.77E+00	1.17E+03	1.62E+02	1.33E+03	1.33E+03
2.92E+01	7.41E-01	2.00E-01	2.81E+02	8.86E-01	2.81E+02	1.33E+02	4.14E+02	4.14E+02
4.37E+01	1.11E+00	3.00E-01	1.24E+02	6.16E-01	1.25E+02	1.22E+02	2.46E+02	2.46E+02
5.83E+01	1.48E+00	4.00E-01	7.05E+01	4.76E-01	7.10E+01	1.16E+02	1.87E+02	1.87E+02
7.29E+01	1.85E+00	5.00E-01	4.58E+01	3.89E-01	4.62E+01	1.12E+02	1.58E+02	1.58E+02
8.75E+01	2.22E+00	6.00E-01	3.15E+01	3.29E-01	3.19E+01	1.08E+02	1.40E+02	1.40E+02
1.17E+02	2.96E+00	8.00E-01	1.62E+01	2.55E-01	1.65E+01	1.02E+02	1.18E+02	1.18E+02
1.46E+02	3.70E+00	1.00E+00	8.67E+00	2.09E-01	8.88E+00	9.80E+01	1.07E+02	1.07E+02
1.82E+02	4.63E+00	1.25E+00	3.36E+00	1.72E-01	3.53E+00	9.44E+01	9.80E+01	9.80E+01
2.19E+02	5.56E+00	1.50E+00	7.54E-01	1.46E-01	9.01E-01	9.01E+01	9.10E+01	9.10E+01
2.55E+02	6.48E+00	1.75E+00	1.14E-01	1.28E-01	2.42E-01	8.62E+01	8.65E+01	8.65E+01
2.92E+02	7.41E+00	2.00E+00	7.19E-03	1.14E-01	1.22E-01	8.28E+01	8.29E+01	8.29E+01
3.65E+02	9.26E+00	2.50E+00	0.00E+00	9.54E-02	9.54E-02	7.73E+01	7.74E+01	7.74E+01
4.37E+02	1.11E+01	3.00E+00	0.00E+00	8.29E-02	8.29E-02	7.30E+01	7.30E+01	7.30E+01
5.10E+02	1.30E+01	3.50E+00	0.00E+00	7.40E-02	7.40E-02	6.90E+01	6.91E+01	6.91E+01
5.83E+02	1.48E+01	4.00E+00	0.00E+00	6.70E-02	6.70E-02	6.60E+01	6.60E+01	6.60E+01
6.56E+02	1.67E+01	4.50E+00	0.00E+00	6.14E-02	6.14E-02	6.20E+01	6.20E+01	6.20E+01
7.29E+02	1.85E+01	5.00E+00	0.00E+00	5.67E-02	5.67E-02	5.83E+01	5.83E+01	5.83E+01
8.75E+02	2.22E+01	6.00E+00	0.00E+00	4.92E-02	4.92E-02	5.35E+01	5.35E+01	5.35E+01
1.17E+03	2.96E+01	8.00E+00	0.00E+00	3.91E-02	3.91E-02	4.53E+01	4.53E+01	4.53E+01
1.46E+03	3.70E+01	1.00E+01	0.00E+00	3.21E-02	3.21E-02	3.84E+01	3.85E+01	3.85E+01

Table 6.3–2
Total Dose at Center of Aluminum Spheres
1.73 Years at Solar Minimum Conditions + 1.27 Years at Solar Maximum Conditions

Z(Mils)	Z(mm)	Z(g/cm2)	Trpd. Elec.	Bremsstr.	EL+BR	Trpd Proton	EL+BR+TRP	Total Dose
1.46E+00	3.70E-02	1.00E-02	7.60E+04	2.87E+01	7.60E+04	2.08E+02	7.62E+04	7.62E+04
2.92E+00	7.40E-02	2.00E-02	4.48E+04	2.08E+01	4.48E+04	1.76E+02	4.50E+04	4.50E+04
4.37E+00	1.11E-01	3.00E-02	2.83E+04	1.59E+01	2.83E+04	1.59E+02	2.84E+04	2.84E+04
5.83E+00	1.48E-01	4.00E-02	1.90E+04	1.29E+01	1.90E+04	1.47E+02	1.92E+04	1.92E+04
7.29E+00	1.85E-01	5.00E-02	1.34E+04	1.07E+01	1.34E+04	1.40E+02	1.36E+03	1.36E+04
8.75E+00	2.22E-01	6.00E-02	9.80E+03	9.03E+00	9.81E+03	1.34E+02	9.94E+03	9.94E+03
1.02E+01	2.59E-01	7.00E-02	7.32E+03	7.70E+00	7.33E+03	1.28E+02	7.46E+03	7.46E+03
1.17E+01	2.96E-01	8.00E-02	5.55E+03	6.63E+00	5.56E+03	1.25E+02	5.68E+03	5.68E+03
1.31E+01	3.33E-01	9.00E-02	4.25E+03	5.77E+00	4.26E+03	1.21E+02	4.38E+03	4.38E+03
1.46E+01	3.70E-01	1.00E-01	3.25E+03	5.07E+00	3.25E+03	1.17E+02	3.37E+03	3.37E+03
2.92E+01	7.41E-01	2.00E-01	5.04E+02	2.32E+00	5.06E+02	9.48E+01	6.01E+02	6.01E+02
4.37E+01	1.11E+00	3.00E-01	1.85E+02	1.57E+00	1.86E+02	8.66E+01	2.73E+02	2.73E+02
5.83E+01	1.48E+00	4.00E-01	9.73E+01	1.20E+00	9.85E+01	8.23E+01	1.81E+02	1.81E+02
7.29E+01	1.85E+00	5.00E-01	6.21E+01	9.79E-01	6.31E+01	7.91E+01	1.42E+02	1.42E+02
8.75E+01	2.22E+00	6.00E-01	4.27E+01	8.30E-01	4.35E+01	7.61E+01	1.20E+02	1.20E+02
1.17E+02	2.96E+00	8.00E-01	2.19E+01	6.44E-01	2.25E+01	7.19E+01	9.44E+01	9.44E+01
1.46E+02	3.70E+00	1.00E+00	1.17E+01	5.28E-01	1.22E+01	6.93E+01	8.15E+01	8.15E+01
1.82E+02	4.63E+00	1.25E+00	4.50E+00	4.33E-01	4.93E+00	6.69E+01	7.18E+01	7.18E+01
2.19E+02	5.56E+00	1.50E+00	9.99E-01	3.69E-01	1.37E+00	6.40E+01	6.54E+01	6.54E+01
2.55E+02	6.48E+00	1.75E+00	1.48E-01	3.22E-01	4.70E-01	6.15E+01	6.20E+01	6.20E+01
2.92E+02	7.41E+00	2.00E+00	9.34E-03	2.86E-01	2.96E-01	5.93E+01	5.95E+01	5.95E+01
3.65E+02	9.26E+00	2.50E+00	0.00E+00	2.37E-01	2.37E-01	5.58E+01	5.60E+01	5.60E+01
4.37E+02	1.11E+01	3.00E+00	0.00E+00	2.04E-01	2.04E-01	5.30E+01	5.32E+01	5.32E+01
5.10E+02	1.30E+01	3.50E+00	0.00E+00	1.80E-01	1.80E-01	5.04E+01	5.06E+01	5.06E+01
5.83E+02	1.48E+01	4.00E+00	0.00E+00	1.62E-01	1.62E-01	4.84E+01	4.86E+01	4.86E+01
6.56E+02	1.67E+01	4.50E+00	0.00E+00	1.47E-01	1.47E-01	4.57E+01	4.58E+01	4.58E+01
7.29E+02	1.85E+01	5.00E+00	0.00E+00	1.35E-01	1.35E-01	4.32E+01	4.33E+01	4.33E+01
8.75E+02	2.22E+01	6.00E+00	0.00E+00	1.16E-01	1.16E-01	4.00E+01	4.01E+01	4.01E+01
1.17E+03	2.96E+01	8.00E+00	0.00E+00	9.07E-02	9.07E-02	3.45E+01	3.46E+01	3.46E+01
1.46E+03	3.70E+02	1.00E+01	0.00E+00	7.34E-02	7.34E-02	2.98E+01	2.99E+01	2.99E+01

The meteoroid environment encompasses only particles of natural origin. The average mass density for all meteoroids is 0.5 grams per cubic centimeter (g/cm^3) and the average velocity for all meteoroids is 20 kilometers per second (km/sec). The design average meteoroid unshielded surface area flux as a function of mass is shown in Figure 6.5–1.

6.6 ORBITAL DEBRIS

The TRMM spacecraft and the LIS instrument shall consider the potential problems related with the collision with space debris while in orbit.

The orbital debris environment is composed of residue from man-made satellites and launch vehicles. The average velocity for objects smaller than 1 centimeter (cm) is 10 km/sec, and the average mass density is 2.8 g/cm^3. Figure 6.6–1 shows a comparison of the projected orbital debris flux versus debris diameter. Recent studies have shown that orbital debris may follow a curve similar to meteoroids below 0.1 cm, and that the flux shown may need to be increased by as much as a factor of 10 for sizes smaller than 0.01 cm.

6.7 TRANSIENT EVENT RECOVERY

The South Atlantic Anomaly is characterized by an increasing density of energetic protons covering a spectrum of energies in the 1 MeV to 100 MeV range. It may be impossible to attempt to shield sensitive electronics parts for all events caused by these particles. The TRMM spacecraft and the LIS instrument shall be protected by appropriate latch-up detection and recovery circuitry. The flight hardware shall also be capable of tolerating single event upsets induced by the singular or combined effects of cosmic ray ions and geomagnetically trapped protons in the spacecraft environment. The TRMM spacecraft and the LIS instrument electronics that are not part of the signal processing chain shall continue to operate normally while traversing the South Atlantic Anomaly.

6.8 CONTAMINATION

The LIS instrument shall comply with the contamination constraints defined in Section 9 of this ICD.

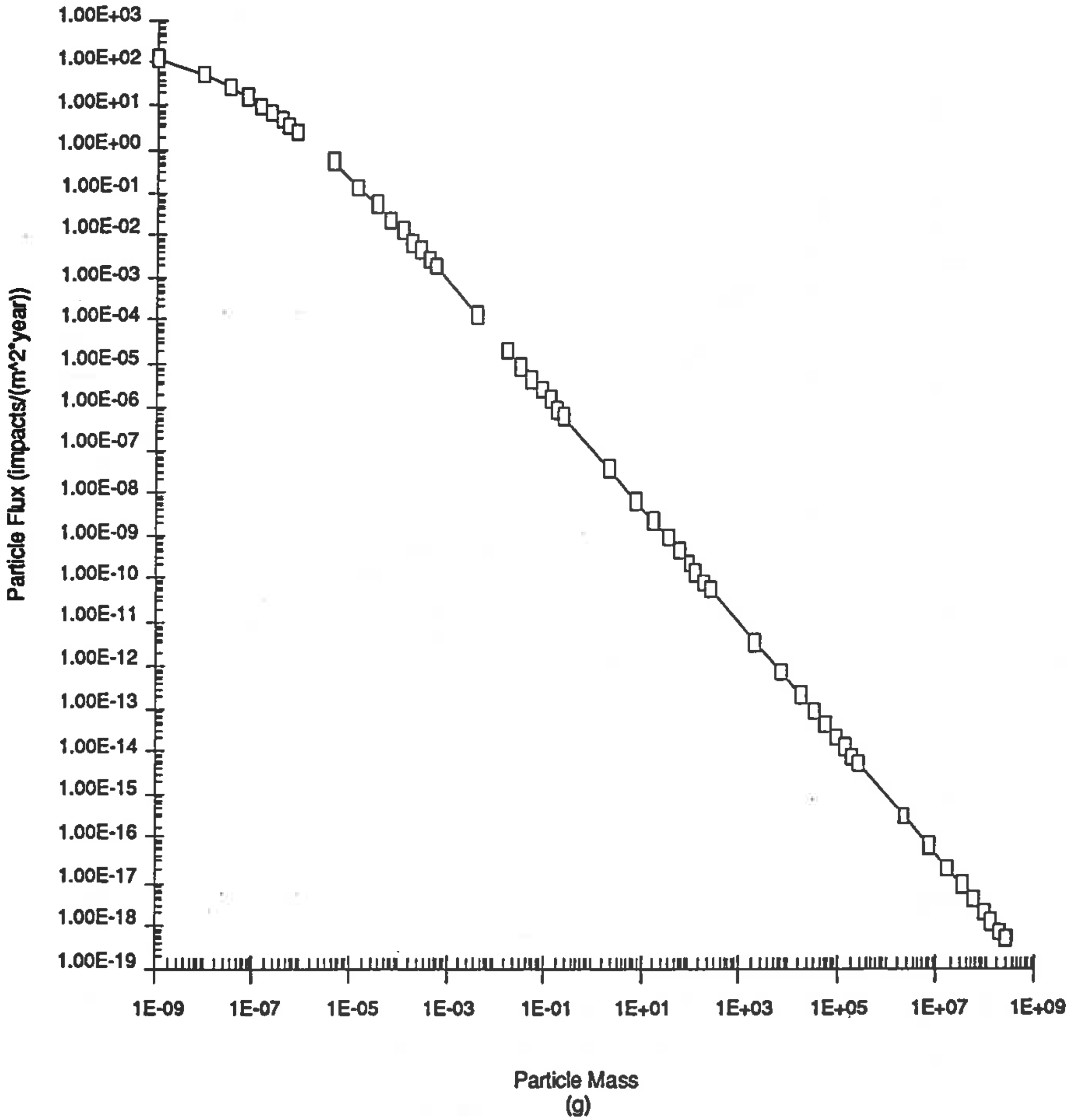


Figure 6.5–1
TRMM 350 km Meteoroid Environment

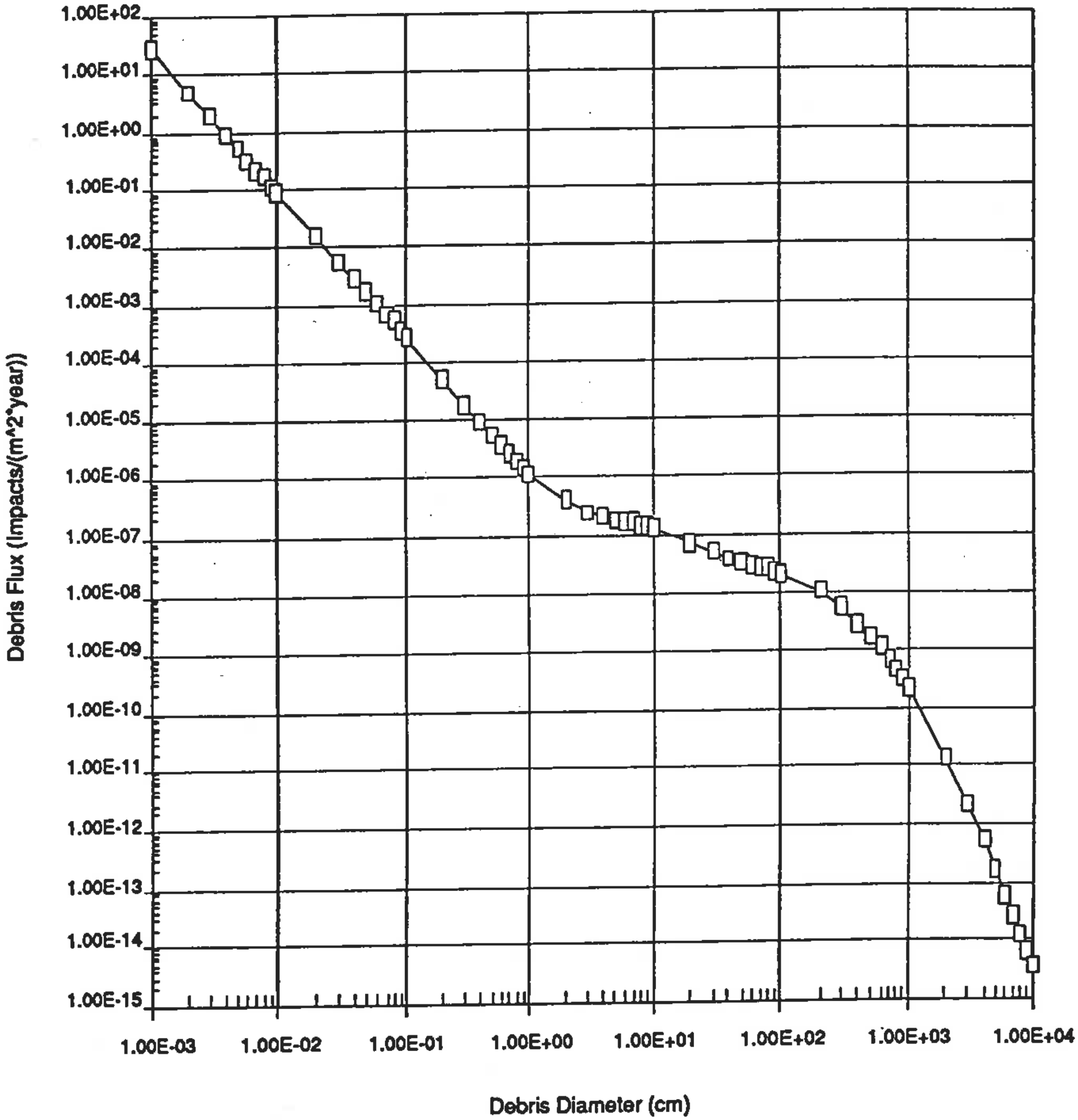


Figure 6.1–1
TRMM: Debris Fluence

7. ELECTRICAL SYSTEM INTERFACES

This section establishes the general requirements for the electrical interfaces between the TRMM spacecraft and the LIS instrument. These interfaces include power and all signals and telemetry not being carried over the MIL-STD-1773 Bus. This section describes flight interfaces only.

7.1 GENERAL

Figure 7.1–1 is the overall TRMM spacecraft to the LIS instrument interface block diagram. The interface between the TRMM spacecraft's FDS and the LIS instrument is shown in Figure 7.1–2. The bus will consist of two fibers for each side (four fibers total) of the redundant bus. The optical characteristics are listed in Table 7.1–1. Figure 7.1–3 is the LIS instrument functional block diagram.

Table 7.1–1
MIL-STD-1773 Terminal Optical Characteristics

ITEM	DESCRIPTION
Optical Connector	SMA 905
Optical wavelength	850 nm
Fiber size to be used	100/140 μm
Coding	Manchester II Bi-phase
Receiver optical sensitivity (with 100/140 micron fiber)	-33 dBm (0.5 μW) minimum -30 dBm (1.0 μW) typical
Transmitter optical output power (with 100/140 micron fiber)	-9.4 dBm (116 μW) minimum -8.4 dBm (145 μW) typical

The control electronics for the TRMM observatory's Electrical Subsystem are two Power Switching and Distribution Units (PSDUs), a Spacecraft PSDU (SPSDU) and an Instrument PSDU (IPSDU). More detailed information on these units can be found in the TRMM Electrical Subsystem ICD (TRMM-733-059).

The IPSDU is the primary TRMM spacecraft interface with the LIS instrument. The IPSDU is a modular assembly responsible for fusing and distributing power from the Power Subsystem, as well as handling any telemetry and discrete command requirements that can not be implemented over the fiber optic bus. These functions are performed by unique modules that are fully redundant within themselves. The IPSDU is made up of one Power Distribution Modules (PDM), one D-Bus Control Module (DCM), two Power Switching Modules (PSM), and two Signal Processing Modules (SPM). The LIS instrument will also interface with the Command Signal Module (CSM) and the Thermistor Monitor Module (TMM).

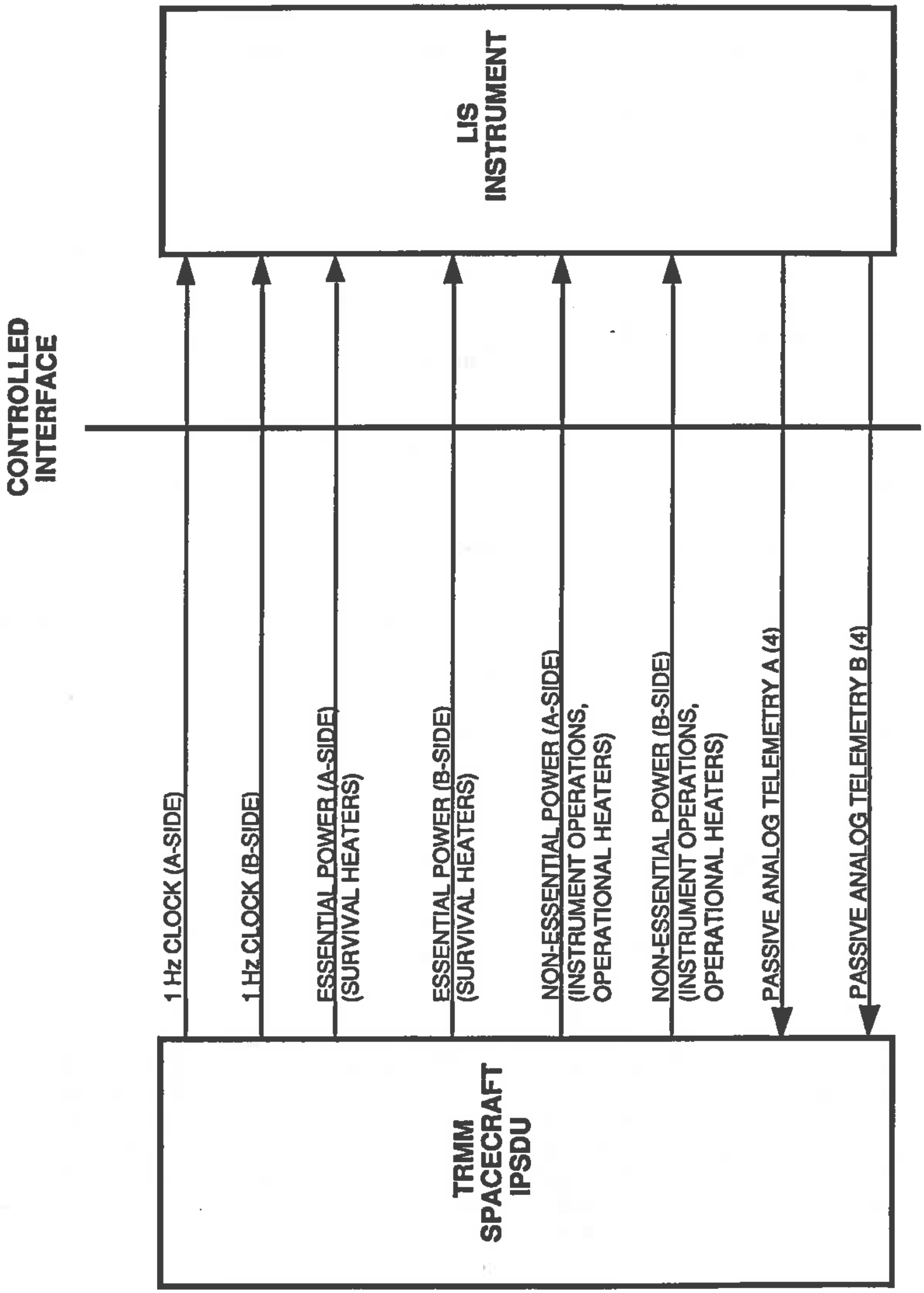


Figure 7.1–1
Electrical Interface Diagram

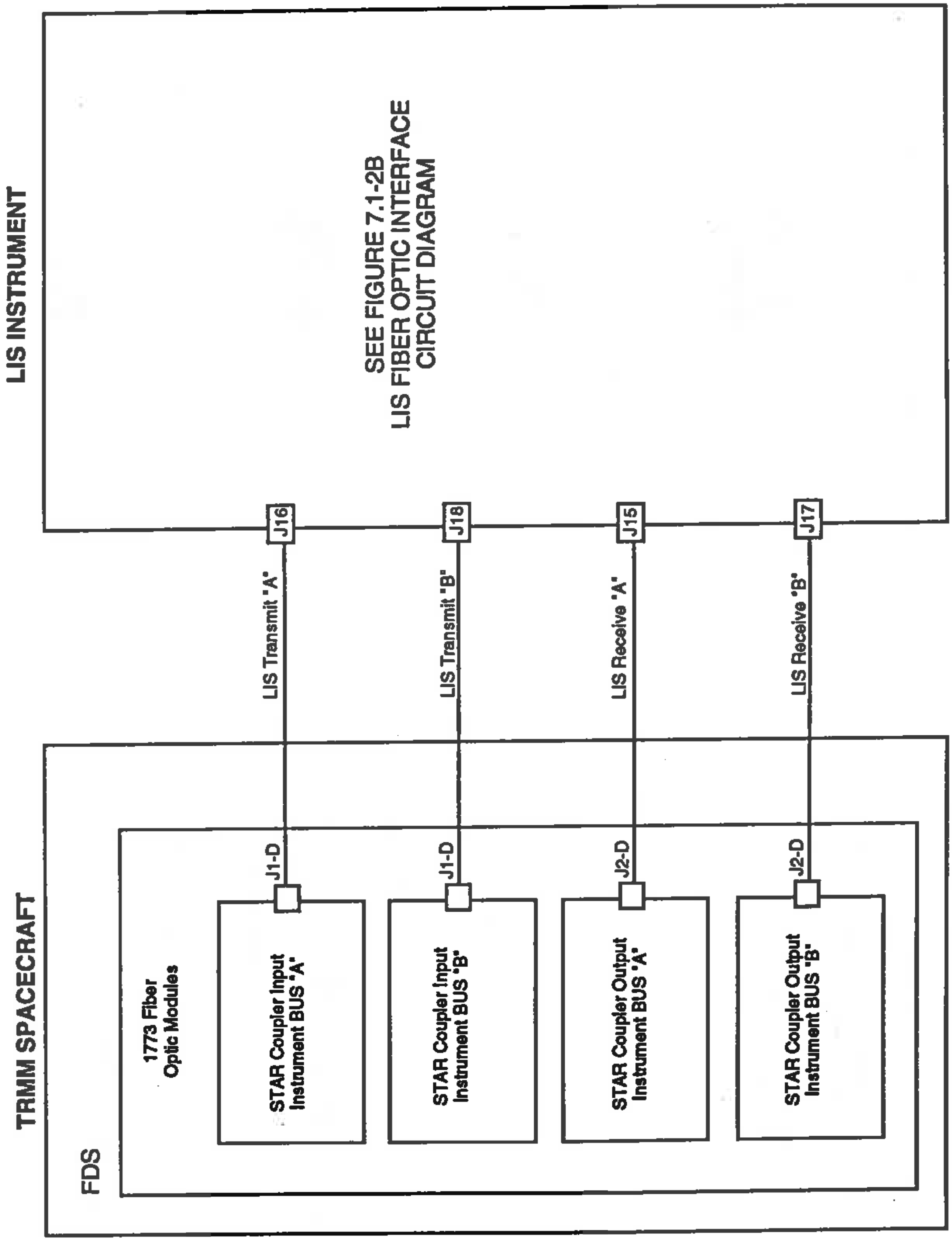


Figure 7.1–2A
FDS/LIS Instrument Optical Bus Interface

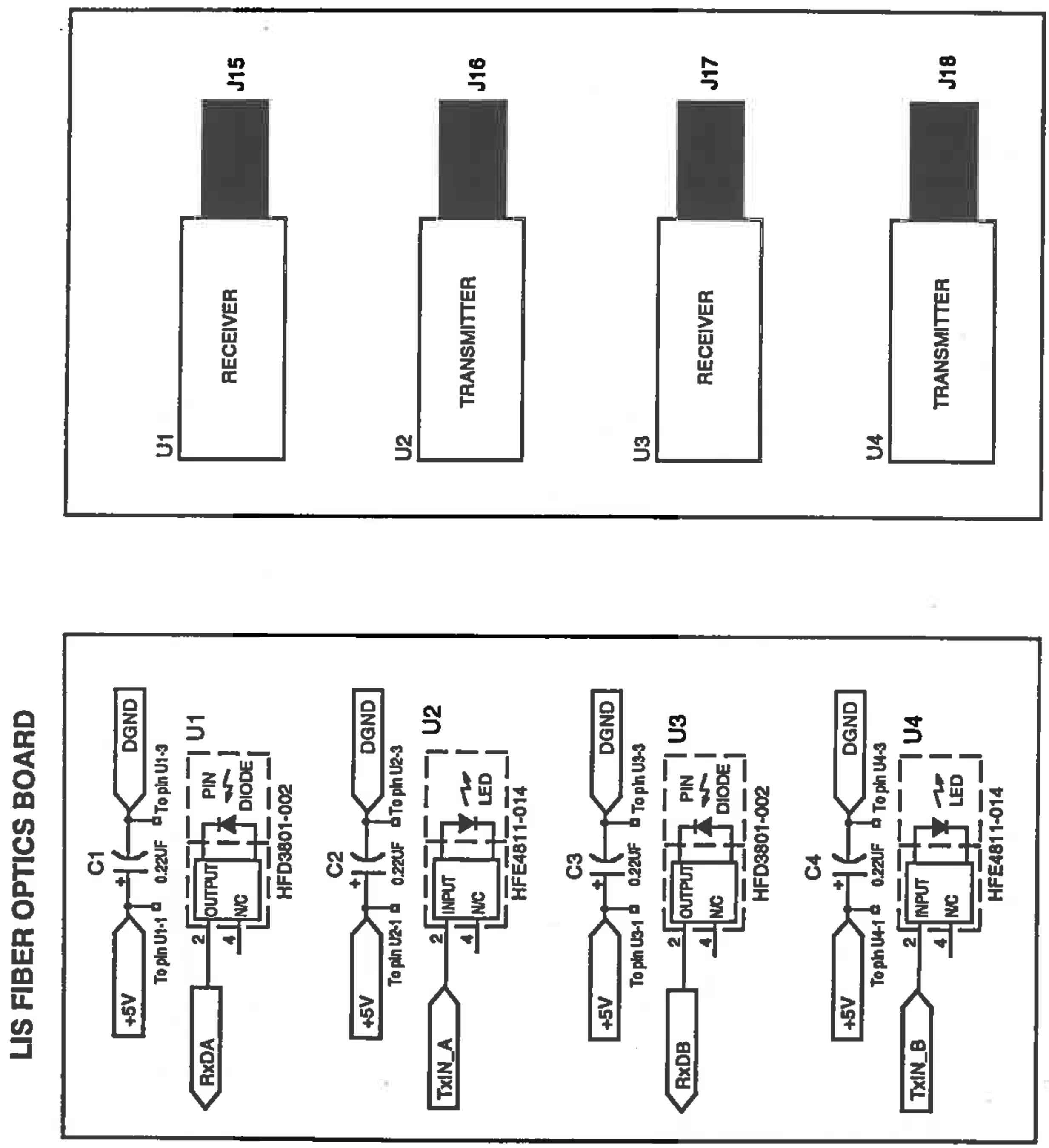


Figure 7.1–2B
LIS Fiber Optic Interface Circuit Diagram

7.2 ELECTRICAL HARNESSING

The following design criteria shall be implemented for utility distribution hardware between the TRMM spacecraft and the LIS instrument:

a. Different type or size of connectors shall be used for signal and power.

b. Selection of different sized connectors shall be used where possible to avoid cable cross connections.

c. Permanent identification of mating connectors shall be provided on both the plug side and the receptacle side of the interface.

d. Plugs or receptacles will incorporate sockets if they are a source of power, and will incorporate pins if they are receiving power.

e. All connectors that will not be used in flight shall have metal captive covers that will be installed prior to launch.

f. All unused circuits shall be properly terminated.

Harnesses between LIS components shall be provided by LIS and fabricated according to the requirements in TRMM-733-043. GSFC will provide any drawings required for LIS to accurately simulate flight cable layout for use in fabrication of LIS cables.

Harnesses between the LIS instrument and the TRMM spacecraft shall be provided by the GSFC and will be built to the detailed requirements defined in the TRMM Electrical Subsystem Specification (TRMM-733-043). MSFC shall provide all necessary connectors for signal and power to GSFC. The preferred connector type is a circular MIL-C-38999 Series III. Figure 7.2–1 shows the locations of J13 through J20, interface connectors to the TRMM spacecraft. The type of connectors on the LIS instrument are indicated in the following tables.

7.3 POWER INTERFACE REQUIREMENTS

7.3.1 Power Management

The TRMM spacecraft will provide two types of redundant power busses to the LIS instrument, an essential bus and a non-essential bus. The essential bus is fused and distributed to the LIS instrument survival heaters. This power will be thermostatically controlled within the LIS instrument. Essential Bus A and Essential Bus B will be powered at all times during the mission, with no switching on the spacecraft side of the interface expected during normal mission operations. This bus is also used to power all spacecraft subsystems required for the normal operation and survival of the TRMM spacecraft.

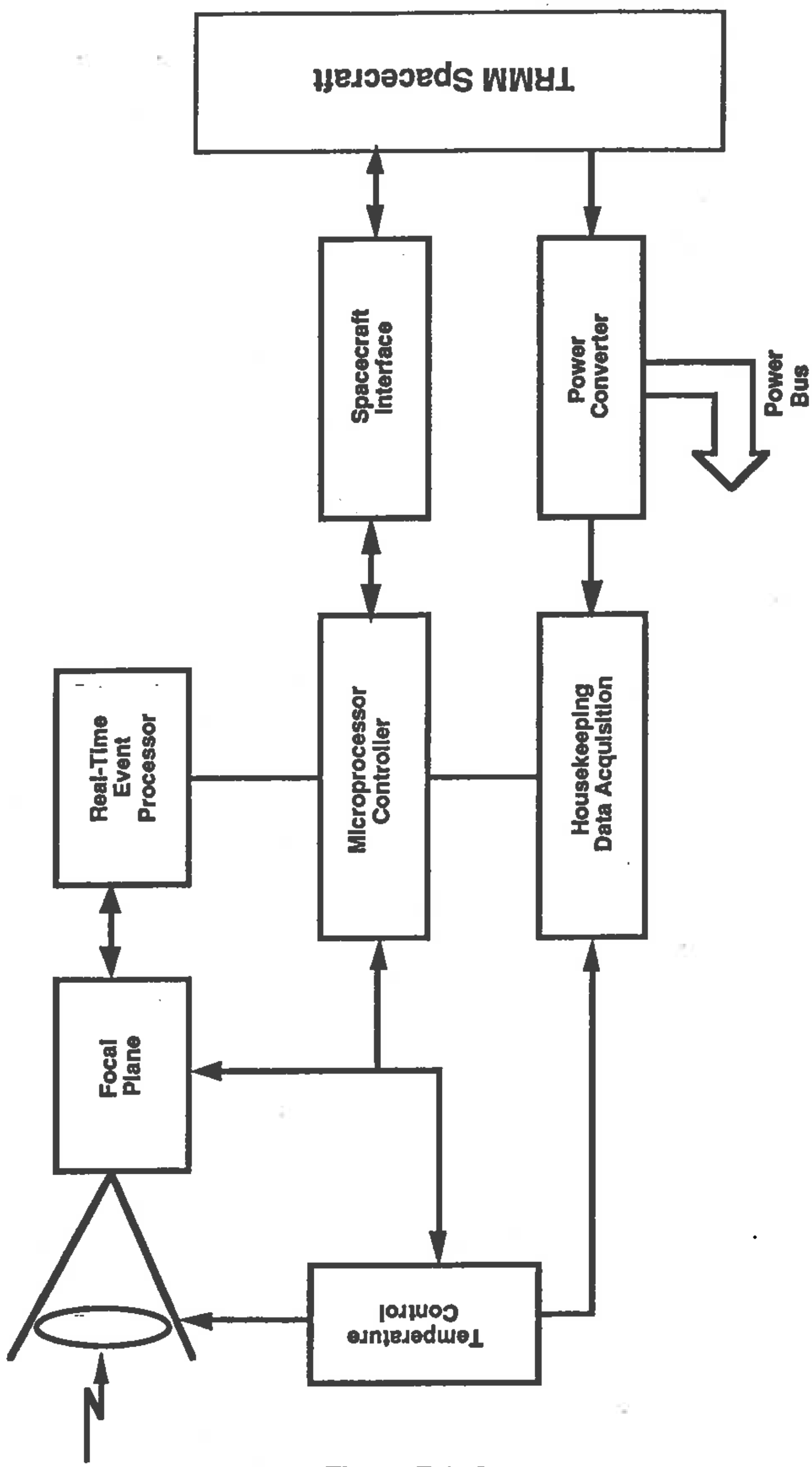


Figure 7.1–3
LIS Instrument Functional Block Diagram

The non-essential bus is fused and switched and is used to power the LIS instrument and any operation heaters required. The LIS instrument shall be able to survive indefinitely without permanent damage with the non-essential power turned off. Operationally, only one of these busses will be powered on at a time. However, the LIS instrument performance shall not be permanently degraded if power is provided simultaneously from the non-essential A bus and non-essential B bus.

The LIS instrument shall be designed so that a failure (either open or short) in either A or B bus does not cause a failure in the remaining bus. This may be accomplished within the LIS instrument in several ways including diode protection or redundant power input circuitry.

7.3.2 Source Requirements

The following section defines the characteristics of the power busses. The LIS instrument shall be designed to operate normally when subjected to these power interface characteristics defined at the LIS instrument's connectors.

7.3.2.1 Steady State Voltage

The LIS instrument shall operate normally with a steady-state voltage input of +28 ±7 Vdc on both busses with superimposed ripple and transients as described in the following paragraphs.

7.3.2.2 Ripple

Spacecraft bus noise and ripple shall be limited to 1.5 volts peak-to-peak maximum over the range from 1 Hz to 10 megahertz (MHz).

7.3.2.3 Single-Event Transients

Single-event transients on the primary power bus due to normal load switching shall be limited to the following values:

- 0 to 10 microseconds (μs) : ± 3.0 volts maximum
- 10 μs to 1.0 millisecond (ms) : ± 2.0 volts maximum
- 1.0 to 50 ms : ± 1.0 volt maximum

The rate of rise of transients of at least 1 millisecond shall be less than 0.5 volts per ms, the rate of fall shall be less than 5.0 volts per ms.

The LIS instrument shall be designed for no degradation of operational performance when subjected to these input conditions. Abnormal observatory operation may result in transients within the range of 0 to + 40 Vdc for periods of up to 500 ms. LIS instrument equipment shall be designed to survive these transients without damage.

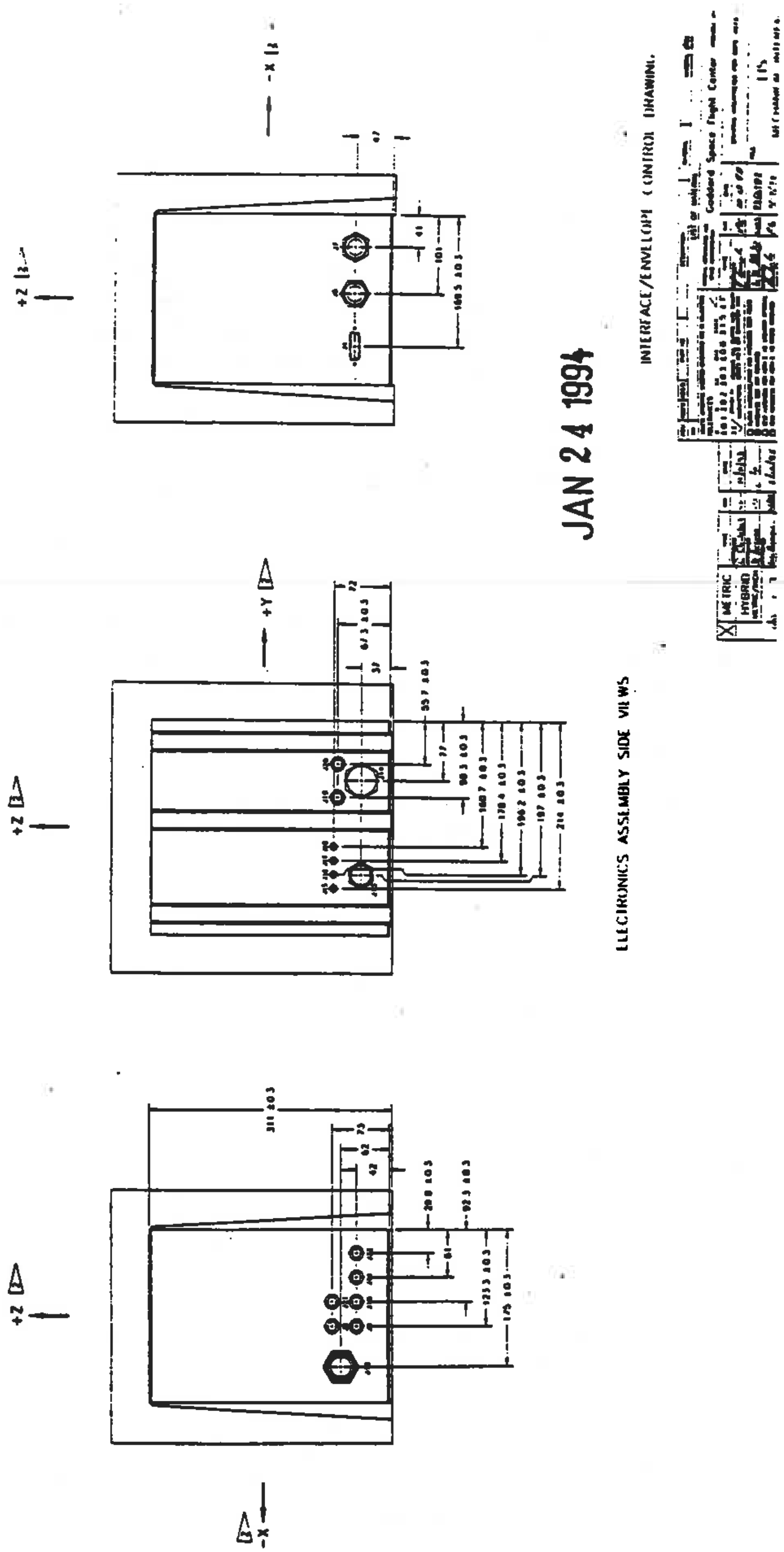


Figure 7.2–1
LIS Instrument Connector Location

7.3.2.4 Bus Impedance

The impedance of the non-essential power lines supplied to the LIS instrument is a combination of the power subsystem and the LIS to power subsystem harness wiring impedance. For the purpose of modeling, the power subsystem impedance may be approximated as a 55 milliohm resistor in series with two microhenries of inductance on each non-essential power and return line supplied to the LIS instrument. The wiring between the LIS instrument and the power subsystem can be modeled as between 3 to 6 meters of harness wire (20 AWG). Figure 7.3-1 depicts this model.

7.3.3 Load Requirements

This section defines the requirements that the LIS instrument must meet at the interface connectors. The power interface connectors and pins are defined in Table 7.3–1. The essential and non-essential power interfaces are shown in Figure 7.3–2.

Table 7.3–1
Power Interface

J13 CHASSIS JACK PART# --- NB7E14-19SNC P13 CABLE PLUG PART# --- NB6GE14-19PNS (TWISTED PAIR)	
PIN #	SIGNAL FUNCTION
A	+28 V Non-Essential Power Input A from PSM
B	
C	+28 V Non-Essential Power Return A to PSM
D	
E	
F	+28 V Non-Essential Power Input B from PSM
G	
H	+28 V Non-Essential Power Return B to PSM
J	
K	
L	+28 V Essential Power to Survival Heaters from PDM A
M	+28 V Essential Power to Survival Heaters from PDM A
N	+28 V Essential Power Return Survival Heaters from PDM A
P	+28 V Essential Power Return Survival Heaters from PDM A
R	
S	+28 V Essential Power to Survival Heaters from PDM B
T	+28 V Essential Power to Survival Heaters from PDM B
U	+28 V Essential Power Return Survival Heaters from PDM B
V	+28 V Essential Power Return Survival Heaters from PDM B

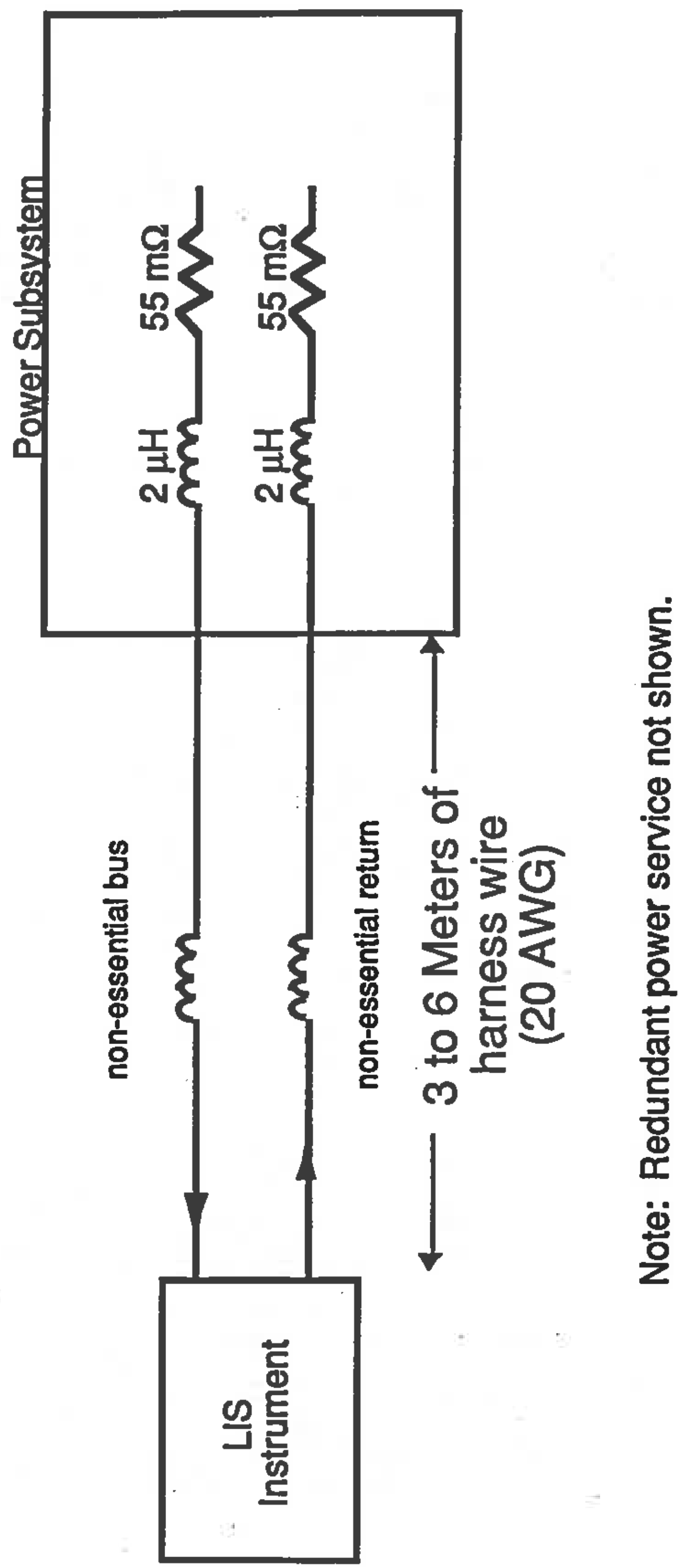


Figure 7.3–1
Power Bus Impedance Model

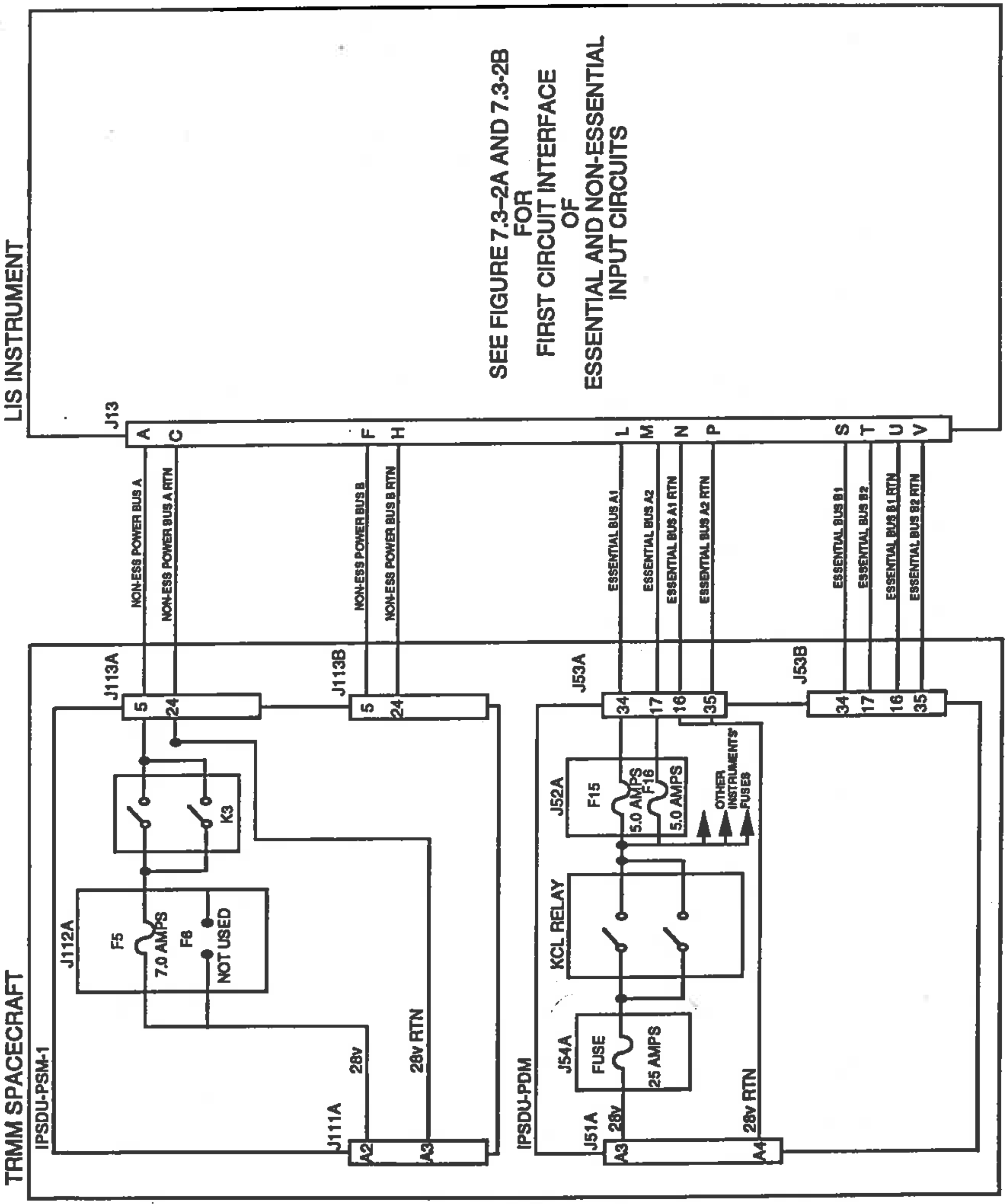


Figure 7.3–2A
Power Bus Interface Diagram

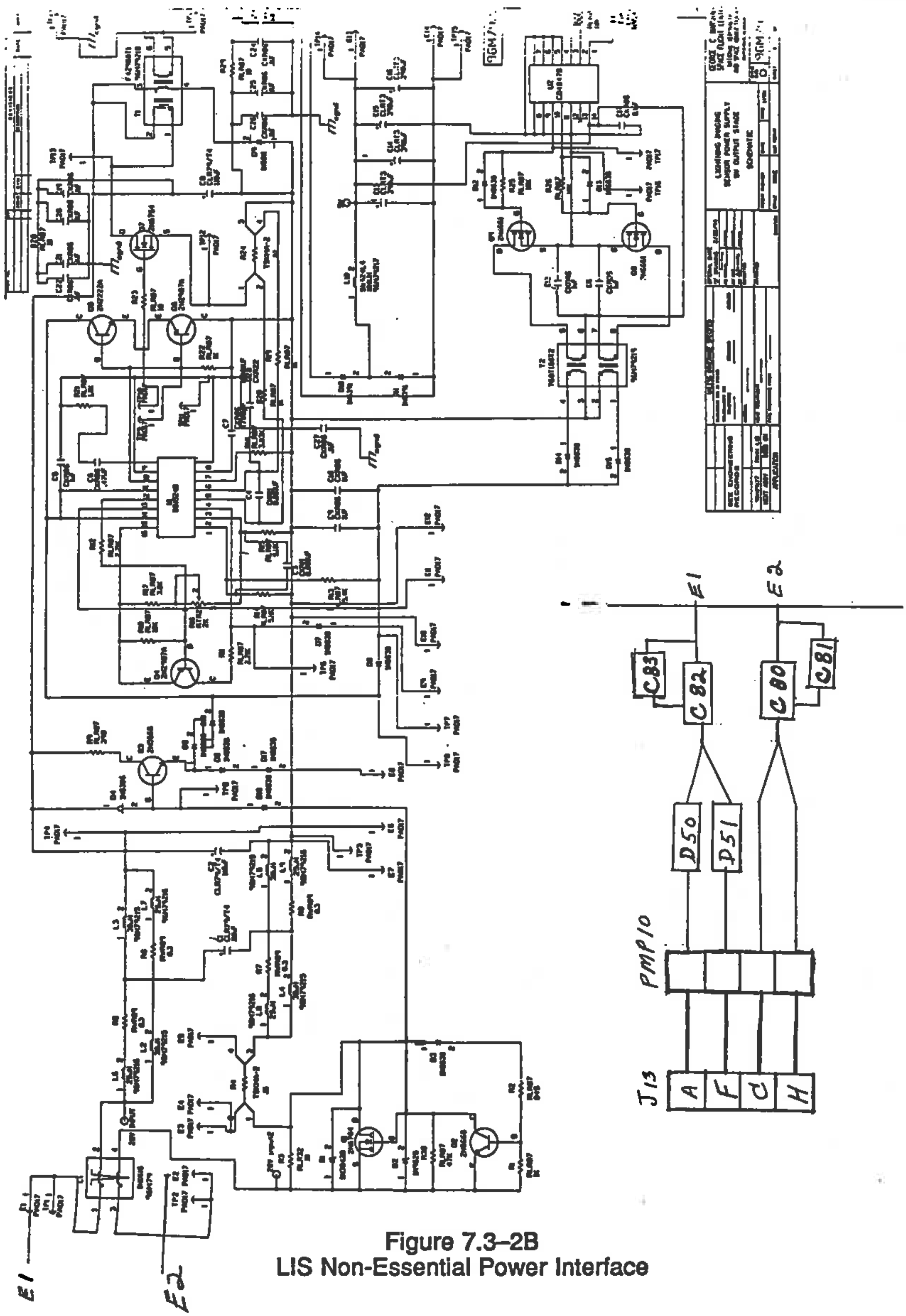


Figure 7.3–2B
LIS Non-Essential Power Interface

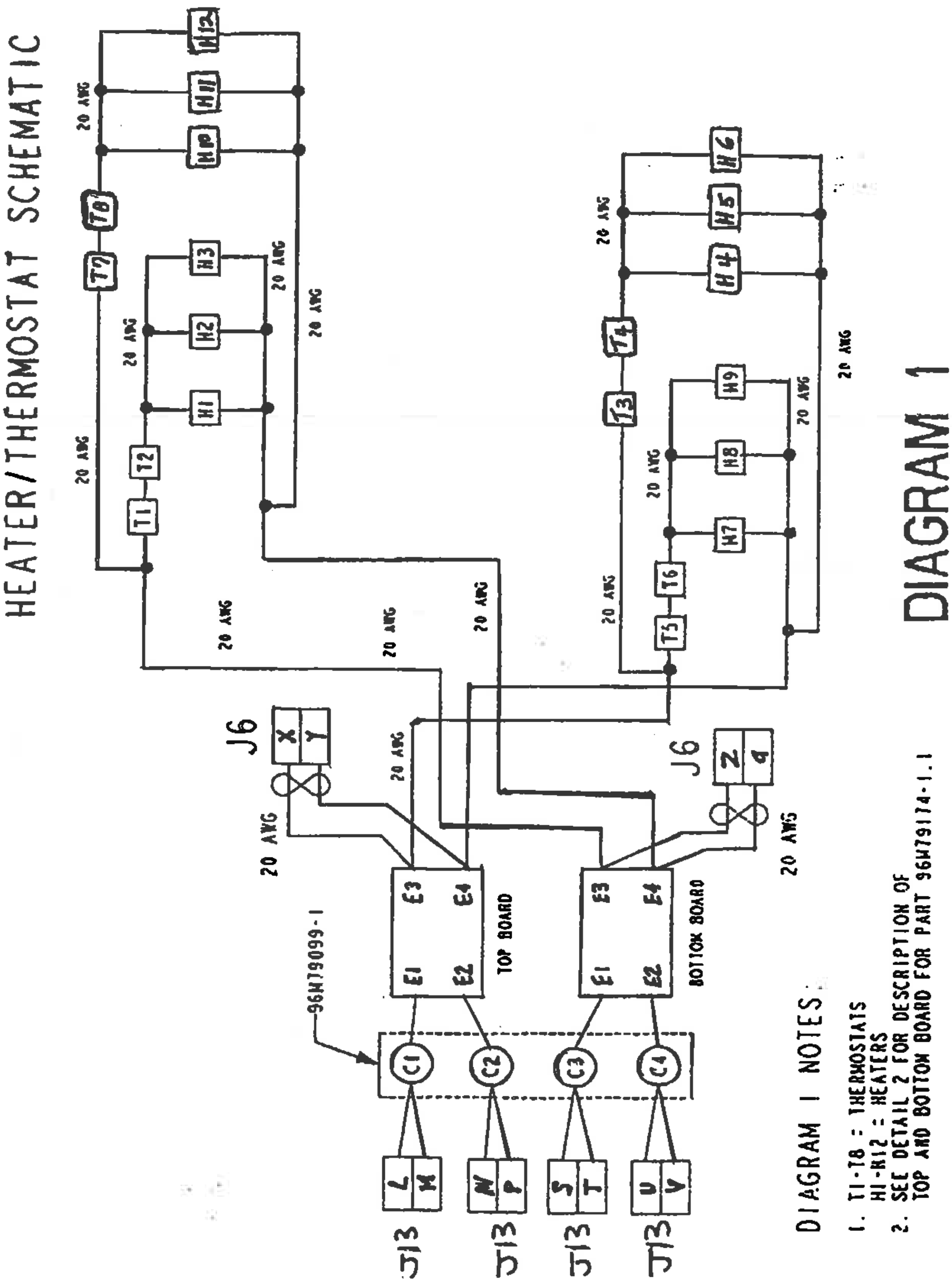


Figure 7.3–2C
LIS Essential Power Interface

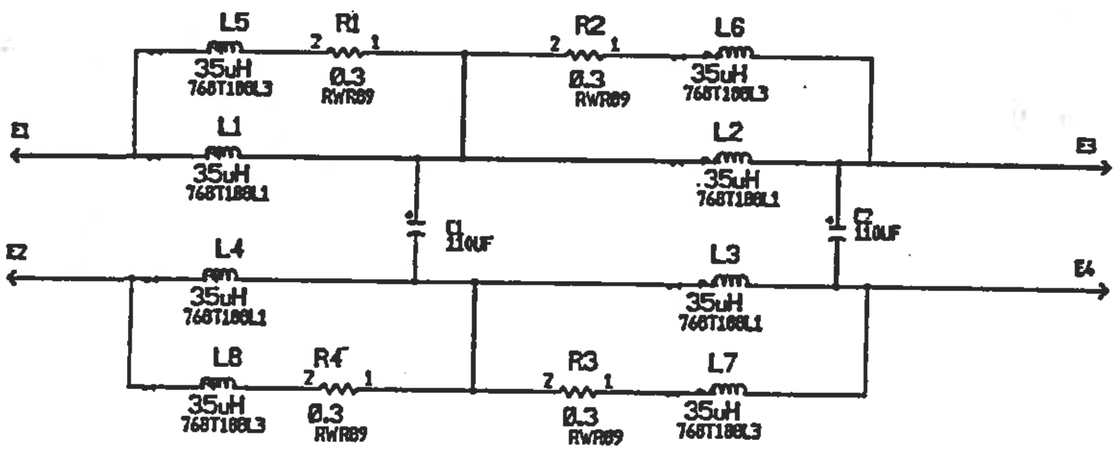


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Figure 7.3–2D
LIS Essential Power Filter

7.3.3.1 Power Quantity Definitions

Three quantities are essential in describing the characteristics and requirements of the power interface supplied to all TRMM components from the PSDUs. These are: peak power, orbital average power, and transients. Transients are further divided into turn-on transients and operational transients. These quantities are defined in the following paragraphs.

Peak power is the value of the maximum power that occurs during normal operations and persists for at least five minutes. Variations in power of 10 percent or less during this period shall be averaged out. This is depicted in Figure 7.3–3.

Orbital average power is the value of the power that occurs during normal operation, averaged over one orbit. Measurements to determine this value must be taken at least every five minutes for the duration of one orbit. This is depicted in Figure 7.3–3.

Transients are defined as short duration changes in the current drawn by a component. Turn-on transients occur in the time region between the closure of the relay supplying power to a component, until 10 seconds after this event. Operational transients occur in the time region between 10 seconds after turn-on and the opening of the relay supplying power to a component. This is depicted in Figure 7.3–4.

7.3.3.2 Input Power

The non-essential operational power for the LIS instrument is 42 W Orbital Average. The peak power requirement is 45 W. This will be provided over one primary and one redundant twisted pair of 20 AWG wire.

The estimated essential power requirements are:

Orbital Avg.	Peak
28w	35w @ 21v
	62w @ 28v
	97w @ 35v per system

Peak power will be required when the LIS instrument is not powered (Initial Oribt Acquisition, Safe Hold, and Low Power Mode). This will be provided over 2 twisted wire pairs of 22 AWG wire.

Redundant sets of non-essential and essential power are provided from side B of the ISPDU.

Note, all of the above power values are maximum values over the voltage range of +21 to +35 Vdc and the heaters are sized for 21 Vdc. The number of wire pairs and fuse sizes are consistent with the GSFC Preferred Parts List (PPL-19 and subsequent) derating guidelines and the specifications described in the TRMM Electrical Subsystem Specification (TRMM-733-043).

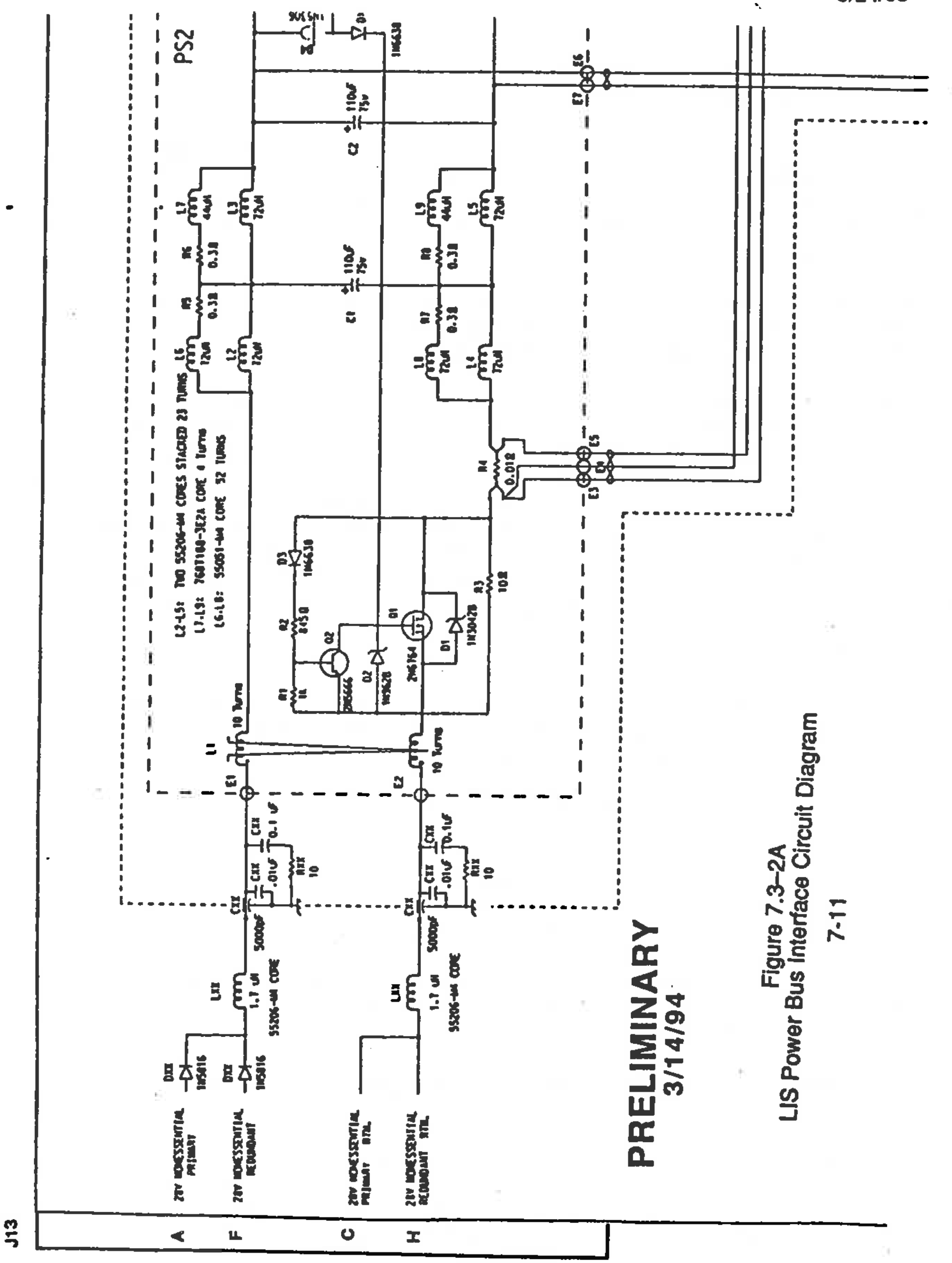


Figure 7.3–2A
LIS Power Bus Interface Circuit Diagram

7.3.3.3 On/Off Control

The TRMM spacecraft will provide primary power switching, through the IPSDU, for all LIS instrument non-essential power inputs. All secondary LIS instrument switching functions shall be accomplished within the LIS instrument and shall be accomplished without the use of mechanical relays unless approved by the TRMM Project. All heater control should be handled with series redundant thermostats. There shall be no LIS instrument switching of heater power except for automatic thermostatic control.

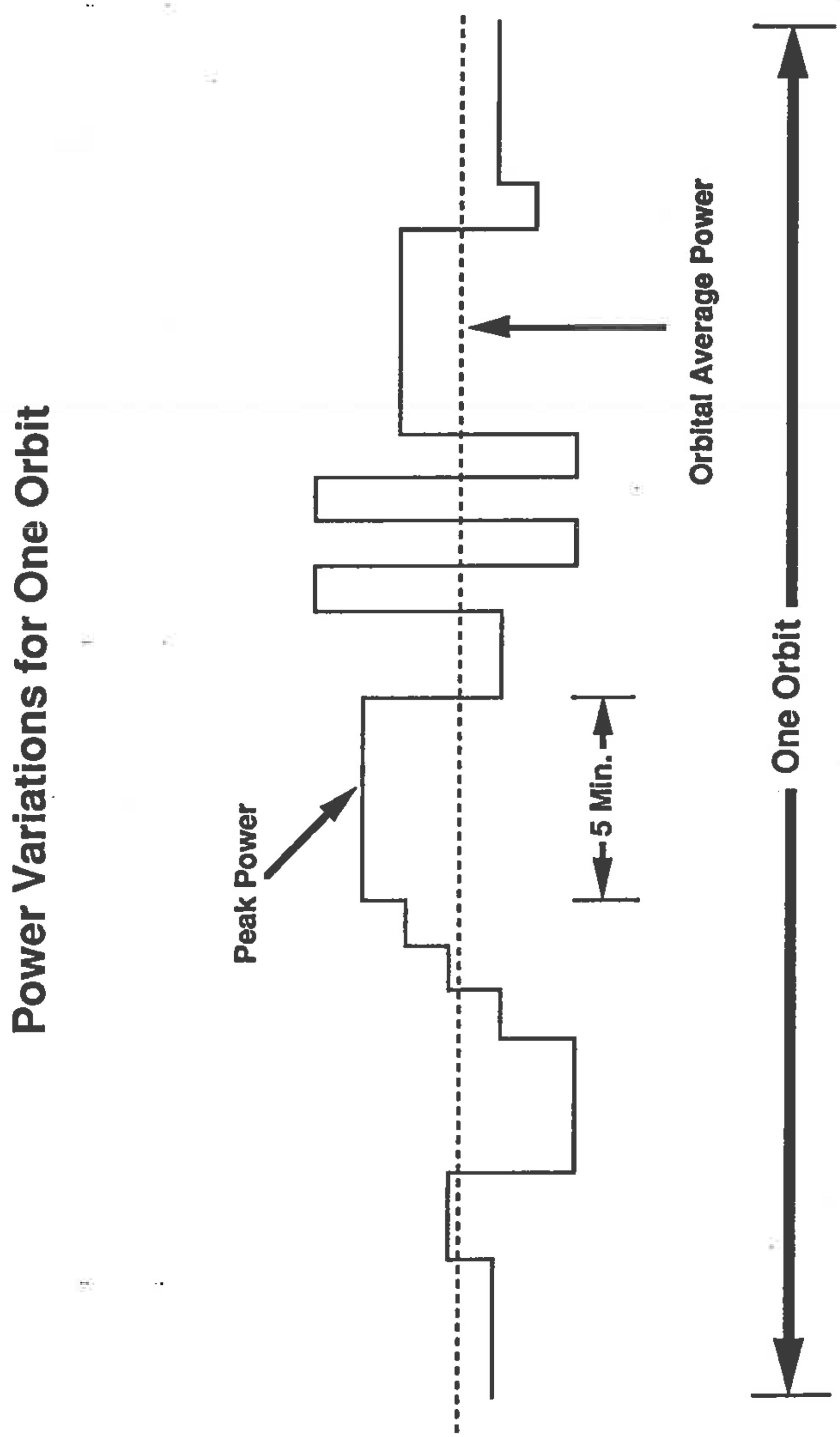


Figure 7.3–3
Peak Power/Orbital Average Power

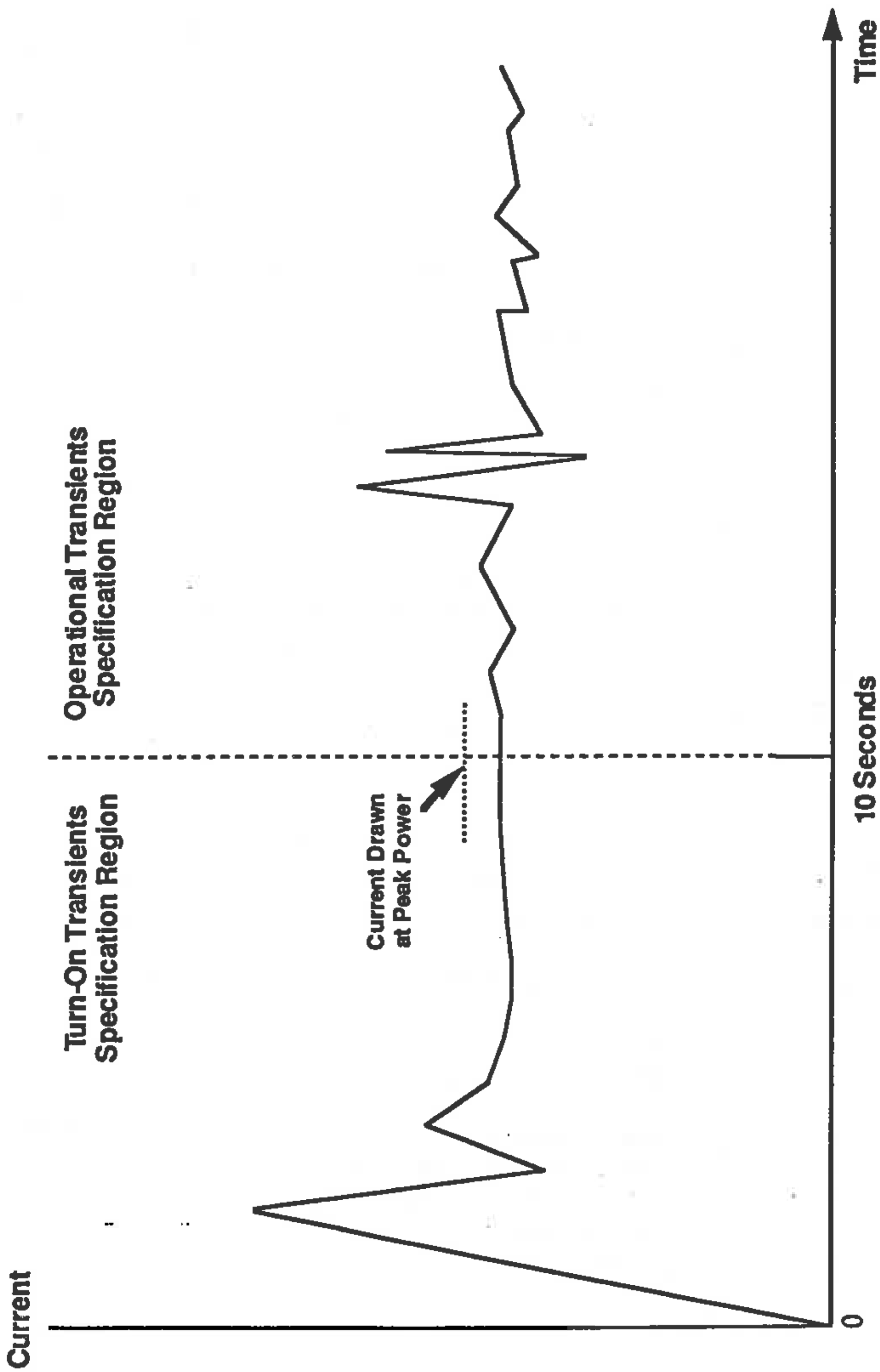


Figure 7.3–4
Transient Definition Regions

Non-essential power can be removed from instrument inputs by ground command or automatically by fault isolation networks, safe hold or low voltage detection. Ground commands are required to reapply power to any subsystem after a power off condition is achieved.

7.3.3.4 Fusing

All power fusing is done in the IPSDU. The LIS instrument will not contain any fuses. The two survival bus lines will each be fused with 5 Amp fuses that are derated to 2.0 Amps for flight. The non-essential power bus will be fused using a 7 Amp fuse, derated to 2.8 Amps for flight. Derating is per PPL-19 and/or PPL-20 with an additional 10% margin to account for temperature effects.

7.3.3.5 Turn On Transients

Turn-on transient current drawn by the LIS instrument shall not exceed the limits shown in Figure 7.3–5. The limit applies with a primary supply voltage from the TRMM spacecraft of 35 volts or less.

The LIS instrument is expected to reach steady state operation within 10 seconds after turn-on. Steady state current is defined as that value of current reached ten seconds after turn on. Current drawn after ten seconds must stay below the limit shown in the figure with the exception of operational transients. Limits for operational transients are specified in section 7.3.3.6. Note that there are no limits for turn-on transients from zero to 1 us after turn-on.

7.3.3.6 Operational Transients

Operational transients shall not exceed 125 percent of the maximum current drawn during peak power operation (25 percent higher than peak operational current). The maximum duration of the transients shall not exceed 50 ms. The rate of change of current during the transients shall not exceed 20 mA/µs. Transients that exceed this specification may cause the TRMM observatory to enter low power mode due to an overcurrent condition.

7.3.3.7 Turn Off Transients

The peak voltage of transients generated by the LIS on the power interface between the LIS and the IPSDU during turnoff due to inductive effects of the load shall not exceed +36 Vdc or drop below -1.0 Vdc with respect to ground. MSFC shall take adequate precautions to prevent damage of parts, such as capacitors or semiconductors, due to polarity reversal.

7.3.3.8 Current Limiting

Passive or active current limiting shall be designed into all subsystems to limit inrush currents. The LIS instrument shall ensure that all operations draw current in a manner acceptable to meet the specifications in this document.

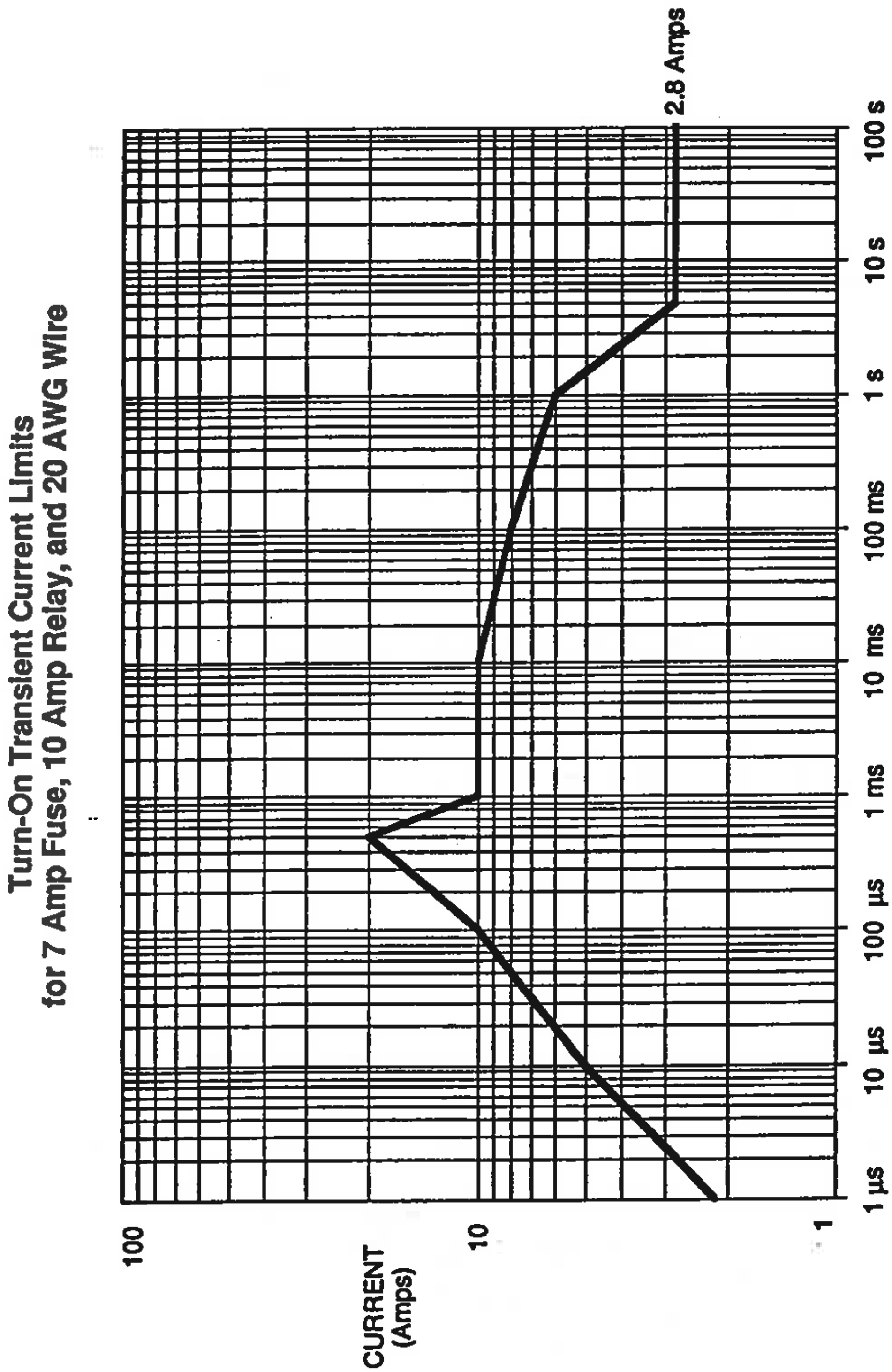


Figure 7.3–5
Turn-on Transient Curve

7.3.3.9 Common Mode Noise

During all normal operations, no component may produce a common mode voltage exceeding 100 millivolts peak-to-peak. The measurements made to verify compliance with this requirement shall be made between primary power and chassis and between primary power return and chassis.

7.3.3.10 Reflected Ripple Current

The fundamental frequency of load current ripple shall not exceed 250 kHz.

7.4 SIGNAL INTERFACE REQUIREMENTS

The signal interface connectors and pins are defined in Table 7.4–1.

Table 7.4–1
LIS Signal Interface

J19 CHASSIS JACK PART# --- BJ76; INTERNAL CABLE = UNSHIELDED TWISTED PAIR P19 CABLE PLUG PART# --- PL75C-210; EXTERNAL CABLE - SHIELDED TWISTED PAIR		
CABLE	PIN #	SIGNAL FUNCTION
CENTER	1	1 HERTZ CLOCK (+) SIDE A
MIDDLE	2	1 HERTZ CLOCK (-) SIDE A
OUTER	SHIELD	CHASSIS GROUND

J20 CHASSIS JACK PART# --- BJ76; INTERNAL CABLE = UNSHIELDED TWISTED PAIR P20 CABLE PLUG PART# --- PL75C-210; EXTERNAL CABLE - SHIELDED TWISTED PAIR		
CABLE	PIN #	SIGNAL FUNCTION
CENTER	1	1 HERTZ CLOCK (+) SIDE B
MIDDLE	2	1 HERTZ CLOCK (-) SIDE B
OUTER	SHIELD	CHASSIS GROUND

7.4.1 General

Unless otherwise noted, all signal requirements are defined and should be measured as follows:

a. Pulse rise time is defined as the elapsed time from 10 to 90 percent of the steady-state amplitude.

b. Pulse fall time is defined as the elapsed time from 90 to 10 percent of the steady-state amplitude.

c. Pulse duration is defined as the elapsed time from 50 percent of the pulse rise amplitude to 50 percent of the pulse fall amplitude.

7.4.2 Safe Hold/Low Power Warning Signal Interface

This signal is available from the TRMM spacecraft but is not required, or used by the LIS instrument.

7.4.3 Clock Interface

The 1 Hz clock signal is a synchronizing pulse that will be used in conjunction with the spacecraft time broadcast on the MIL-STD-1773 bus to establish time throughout the TRMM spacecraft. The 1 Hz pulse synchronizes the declaration of the spacecraft time to the user. The rising edge is the synchronizing edge. See Figure 7.4-1 for the clock interface circuit diagram.

The PSDU receives the 1Hz clock from the C&DH subsystem and redistributes it to the instrument using differential drivers. The PSDU has the ability to distribute either the C&DH A Clock or the C&DH B Clock depending on which is active. The clock will come from either the A or B side of the PSDU. The other side will be inactive (High impedance) under normal conditions.

If both sides of the PSDU are on, (an abnormal but possible condition) the clock will be provided from both PSDU A and PSDU B. Normally, these clocks have the same source, and therefore will be in sync (plus or minus a gate delay or so). However, it is possible that out of sync A and B clocks may be provided by the PSDU. The LIS instrument shall not be degraded by this condition. If this happens, or if a side of the PSDU has malfunctioned, the clock signal from one PSDU can be disabled by commanding the PSDU. All of this clock selection is controlled procedurally, there are no hardware interlocks to prevent simultaneous transmission of out of sync clocks.

If required by an instrument, a 1773 command can tell an instrument which clock to listen to. This is done by ground controllers determining the status of the PSDU through information regularly in PSDU telemetry. Then a command can be sent by instrument ground controllers to an instrument telling the instrument which clock to use. The instrument provider is responsible for implementation of the command in the instrument and in the IGSE and must adhere to all applicable TRMM software requirements.

The differential interface used for the 1Hz clock signal is a 26C31. Pull-up termination on the LIS side is suggested.

7.4.4 Passive Analog Telemetry Interface

The IPSDU will provide the LIS instrument with up to 8 passive analog channels (4 prime or A-side and 4 redundant or B-side). These are typically, but not restricted to, thermistor inputs. A 1 mA pulse will be provided to the circuit. The IPSDU circuitry is designed to accommodate the "Suggested Thermistor" (ref. TRMM-733-043) part number 311P18-02576R. A 10K ohm resistor in parallel with the thermistor is required as a compensating network and will be provided within the IPSDU.

Transducers other than the standard thermistors may be used with these passive analog channels subject to the following restrictions:

- The transducer shall be combined with the necessary resistance value such that its characteristic is equivalent to the TRMM standard thermistor, or
- the appropriate calibration curve(s) is provided to GSFC for inclusion in the TRMM data base.

Limit switches or similar bi-level devices are exempt from these restrictions.

These inputs will be sent down in the telemetry stream even during LIS instrument non-operating modes. These inputs are separate and in addition to any passive analog (thermistor) inputs going through the MIL-STD-1773 bus interface. All channels will be carried on twisted bundle shielded 5 conductor cable with 4 data lines and 1 current return line. See Figure 7.4–2 for the interface characteristics. See Table 7.4–2 for preliminary information on connector type and pin assignments.

Entirely separate transducers are to be used for the passive analog circuits. Transducers are not to be grounded within the LIS instrument. Line capacitance for each passive transducer circuit is to be less than 300 pF within the LIS instrument and less than 500 pF in the spacecraft cabling (with 10K ohms load impedance). Passive analog telemetry shall be telemetered at least once every 5 minutes in the 1 kbps telemetry modes and at least once every minute in all other telemetry modes. Pulse width and Repetition rate are flight software dependent.

7.5 ELECTROMAGNETIC INTERFERENCE/COMPATIBILITY REQUIREMENTS

The following section covers design and specification concepts established to protect sensitive equipment from environmental or TRMM observatory electromagnetic interference (EMI) and prevent any degradation of system performance.

Table 7.4–2
LIS Passive Analog Connector

J14 CHASSIS JACK PART# --- NLS7E16-35S
P14 CABLE PLUG PART# --- NLS6GE16-35P (EXTERNAL CABLE)
(TWISTED SHIELDED PAIR AWG 24)

PIN#	SIGNAL FUNCTION	SYMBOL NAME	REMARKS
1	OPTICS FILTER TEMPERATURE PRIMARY	PAPDL1	PRIMARY PASSIVE ANALOG-1 TO SPM-A
2	OPTICS FILTER TEMPERATURE PRIMARY RETURN	PAPCR1	
3	FOCAL PLANE ARRAY TEMPERATURE PRIMARY	PAPDL2	PRIMARY PASSIVE ANALOG-2 TO SPM-A
4	FOCAL PLANE ARRAY TEMPERATURE PRIMARY RETURN	PAPCR2	
5	SENSOR HEAD ASSEMBLY TEMPERATURE PRIMARY	PAPDL3	PRIMARY PASSIVE ANALOG-3 TO SPM-A
6	SENSOR HEAD ASSEMBLY TEMERATURE PRIMARY RETURN	PAPCR3	
7	ELECTRONIC ASSEMBLY TEMPERATURE PRIMARY	PAPDL4	PRIMARY PASSIVE ANALOG-4 TO SPM-A
8	ELECTRONIC ASSEMBLY TEMPERATURE PRIMARY RETURN	PAPCR4	
9	OPTICS FILTER TEMPERATURE REDUNDANT	PARDL1	REDUNDANT PASSIVE ANALOG-1 TO SPM-B
10	OPTICS FILTER TEMPERATURE REDUNDANT RETURN	PARCR1	
11	FOCAL PLANE ARRAY TEMPERATURE REDUNDANT	PARDL2	REDUNDANT PASSIVE ANALOG-2 TO SPM-B
12	FOCAL PLANE ARRAY TEMPERATURE REDUNDANT RETURN	PARCR2	
13	SENSOR HEAD ASSEMBLY TEMPERATURE REDUNDANT	PARDL3	REDUNDANT PASSIVE ANALOG-3 TO SPM-B
14	SENSOR HEAD ASSEMBLY TEMPERATURE REDUNDANT RETURN	PARCR3	
15	ELECTRONIC ASSEMBLY TEMPERATURE REDUNDANT	PARDL4	REDUNDANT PASSIVE ANALOG-4 TO SPM-B
16	ELECTRONIC ASSEMBLY TEMPERATURE REDUNDANT RETURN	PARCR4	
17-35	PINS 17 THROUGH 35 ARE NOT USED.		

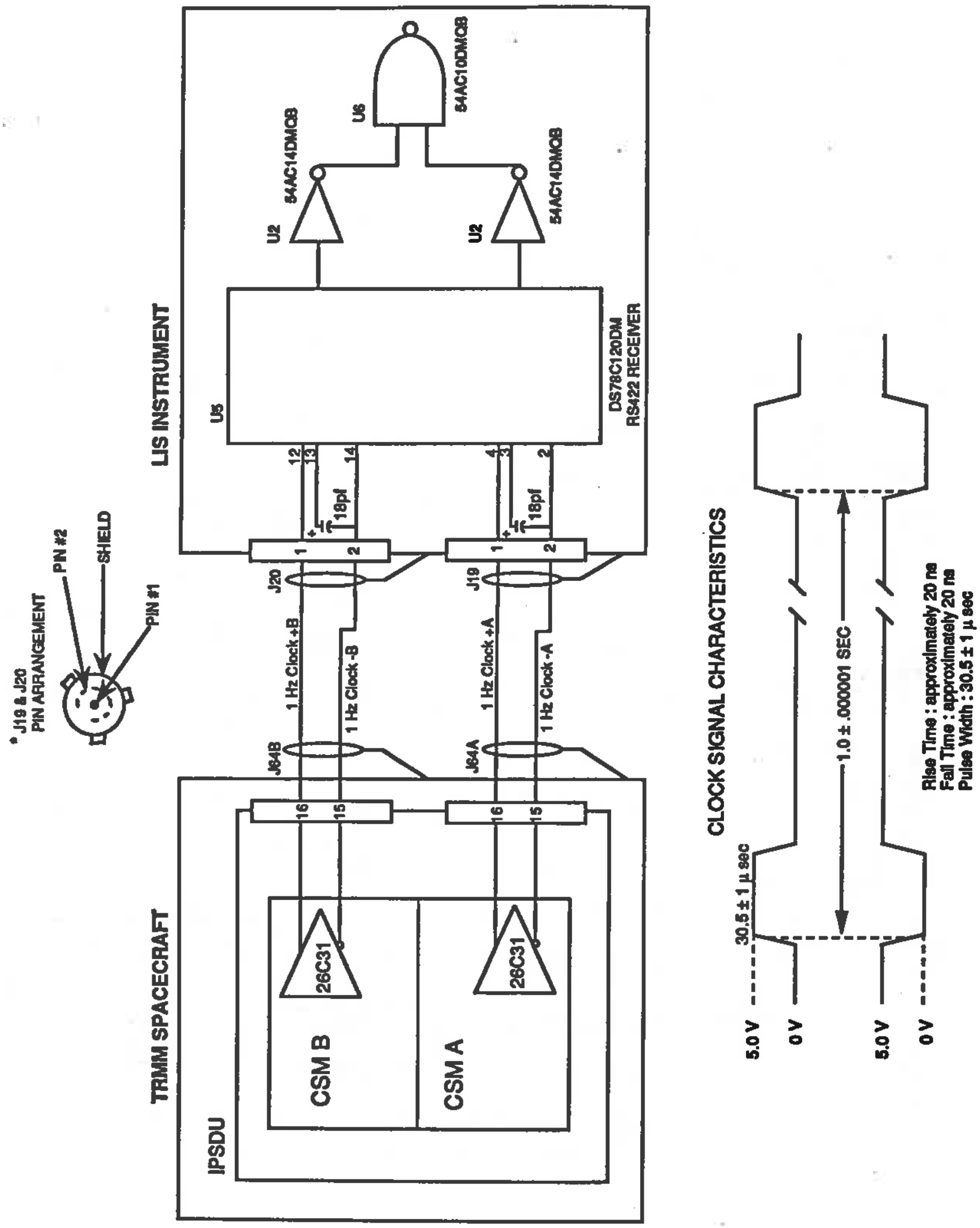


Figure 7.4-1
1.0 Hz Clock Characteristics

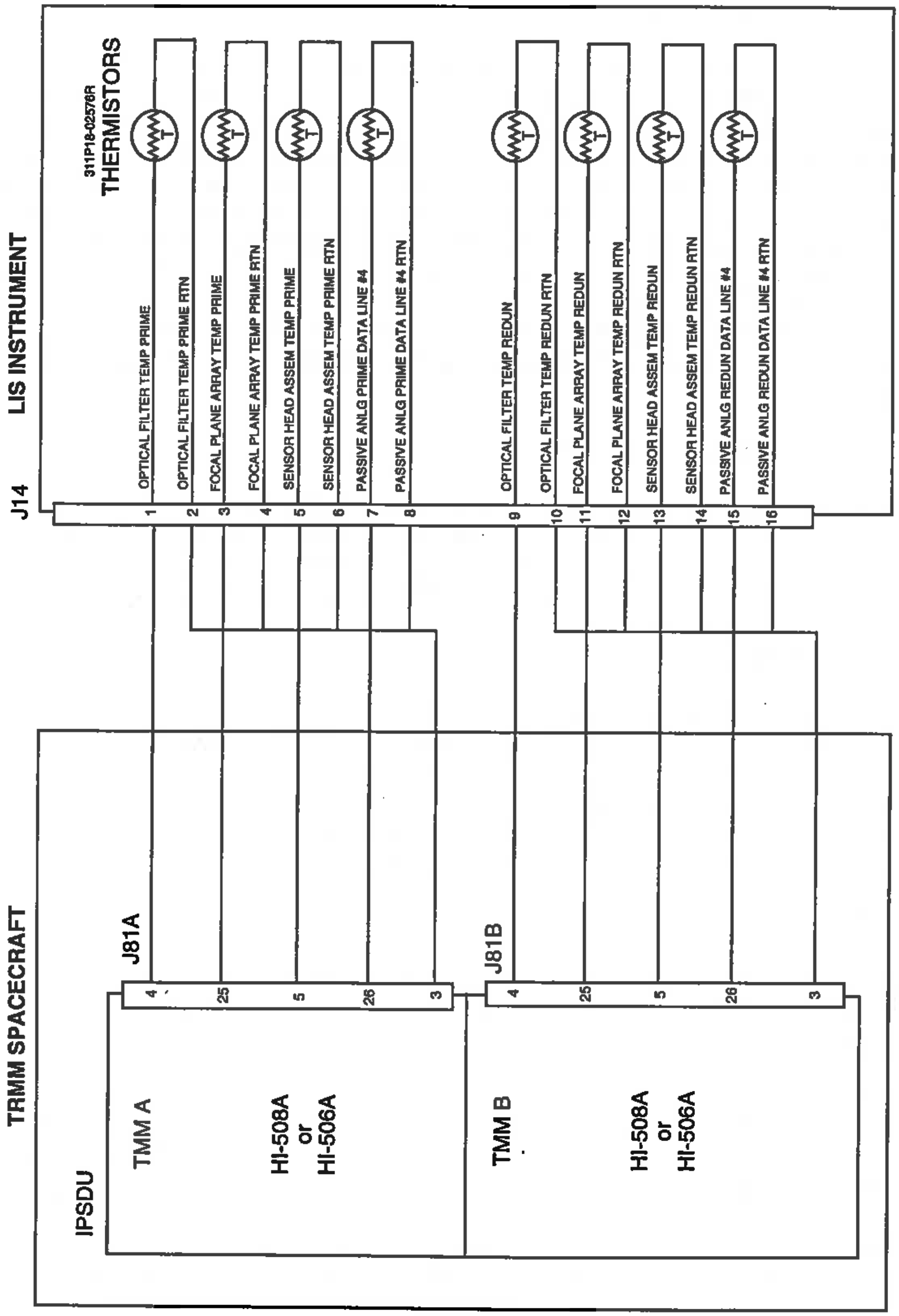


Figure 7.4–2
Passive Analog Interfaces

7.5.1 Instrument Testing

To ensure self compatibility, and compatibility with the launch vehicle, the TRMM spacecraft will undergo a series of electromagnetic interference and electromagnetic compatibility (EMI/EMC) tests. Since the cost and difficulty of EMI control increases as the spacecraft becomes more complex, individual subsystems and instruments will be required to perform tests to levels that are more stringent than those of the spacecraft as a whole. Allowed emissions by the LIS instrument will be for subsystems, instruments and components as required in the TRMM PAR (TRMM-303-006) and as shown in the "Goddard Environmental Verification Specification for STS & ELV", January 1990 (GEVS-SE) as augmented by the TRMM Electrical Subsystem Specification (TRMM-733-043). These levels are 10 dB lower than those allowed for the spacecraft as a whole. Susceptibility test levels will be as specified in Section 7.5-6 and 7.5-8.

7.5.2 Observatory Level Testing

The TRMM spacecraft will be subjected to all the EMI/EMC testing required by GEVS-SE as augmented by the TRMM Electrical Subsystem Specification (TRMM-733-043). Additional requirements imposed by the launch vehicle or by request of individual subsystems may be performed subject to TRMM project approval.

7.5.3 Electrical Bonding

The electrical dc resistance across the LIS instrument adapter/spacecraft thermal isolator interface shall not exceed 2.5 milliohms. Mating surfaces shall be free from nonconductive finishes and shall have maximum practical contact surface area. Connector shells shall be electrically bonded to the chassis through an electrical resistance not exceeding 5.0 milliohms. Movable metal-to-metal joints may use bonding jumpers providing ≤ 2.5 milliohms of resistance.

7.5.4 Grounding and Isolation

All power drawn for the essential and non-essential busses, except heater circuits, must meet the isolation requirements of this document using a DC-to-DC converter, or other means.

Within the LIS instrument, DC-to-DC converter secondary returns will be tied to chassis. Power returns within subsystems shall be tied to the chassis using the shortest wire length possible. This requirement will allow and encourage connections to the chassis at multiple points.

Power returns for spacecraft power feeding the DC-to-DC converters will be isolated from structure and brought to the spacecraft power system ground. These returns will be isolated from structure by not less than 10 megaohms. All external conductive surfaces or components shall be bonded together so that there is a discharge path.

Figure 7.5–1 shows the overall grounding and bonding scheme.

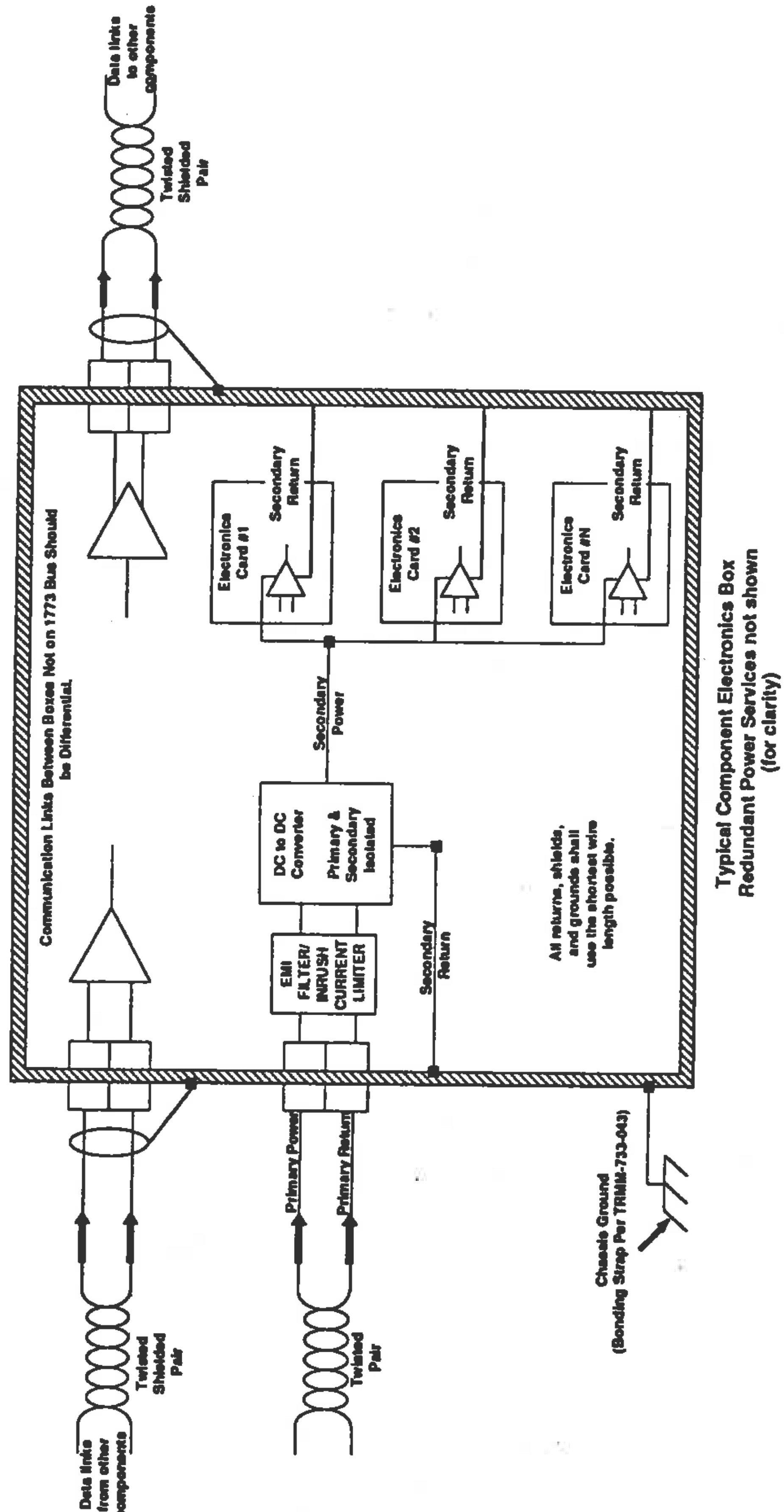


Figure 7.5–1
Grounding and Bonding

7.5.5 Shielding

All unit and assembly enclosures shall be designed to provide continuous shielding to minimize radiation from internal circuitry and susceptibility to external electromagnetic fields.

7.5.6 Conducted Susceptibility

No undesirable response, malfunction, or degradation of performance shall be produced in any subsystem when subjected to the following signals:

a. A sine wave having an amplitude and frequency as shown in Figure 7.5–2 will be superimposed upon each of the LIS instrument's 28VDC input power leads. The test method used will be CS01 and CS02 of MIL-STD-462.

b. A positive or negative transient having an amplitude as shown in Figure 7.5–3 will be superimposed upon each of the LIS instrument's input power leads. The test method used will be CS06 of MIL-STD-462.

7.5.7 Conducted Emissions

The LIS instrument will be required to pass the narrowband and broadband emissions specifications as shown in Figures 7.5–4 and 7.5–5. The test method used will be CE01 and CE03 of MIL-STD-462. The test will be performed on power and return leads of all buses.

Transient current pulses, both single event and recurring, with the exception of initial turn-on transient events, shall be contained within the limits listed in the previous paragraph.

Unless requested by the TRMM project, no observatory level Conducted Emissions testing shall be performed.

7.5.8 Radiated Susceptibility

No undesirable response, malfunction, or degradation of performance shall be produced in any subsystem when subjected to the following signals:

Frequency Range	Test Level
14 kHz – 2 GHz	2 volts/meter
2 GHz – 12 GHz	5 volts/meter
12 GHz - 18 GHz	10 volts/meter*

The test method used will be RS03 of MIL-STD-462.

* This requirement is designed to test for effects on all observatory elements due to the operation of the Precipitation Radar instrument.

7.5.9 Radiated Emissions

Radiated electric field interference from any subsystem or instrument case or wiring shall not exceed the limits shown below and in Figures 7.5–6 and 7.5–7. The test method used will be RE02 of MIL-STD-462.

TRMM RE02 Specifications: Notch Depth and Width Values

Notch Width (MHz)	NB Notch Depth (dBuv/m)	BB Notch Depth (dBuv/m/MHz)
122.0	32.0	11.0
20.0	17.0	18.0
6.0	44.0	35.0

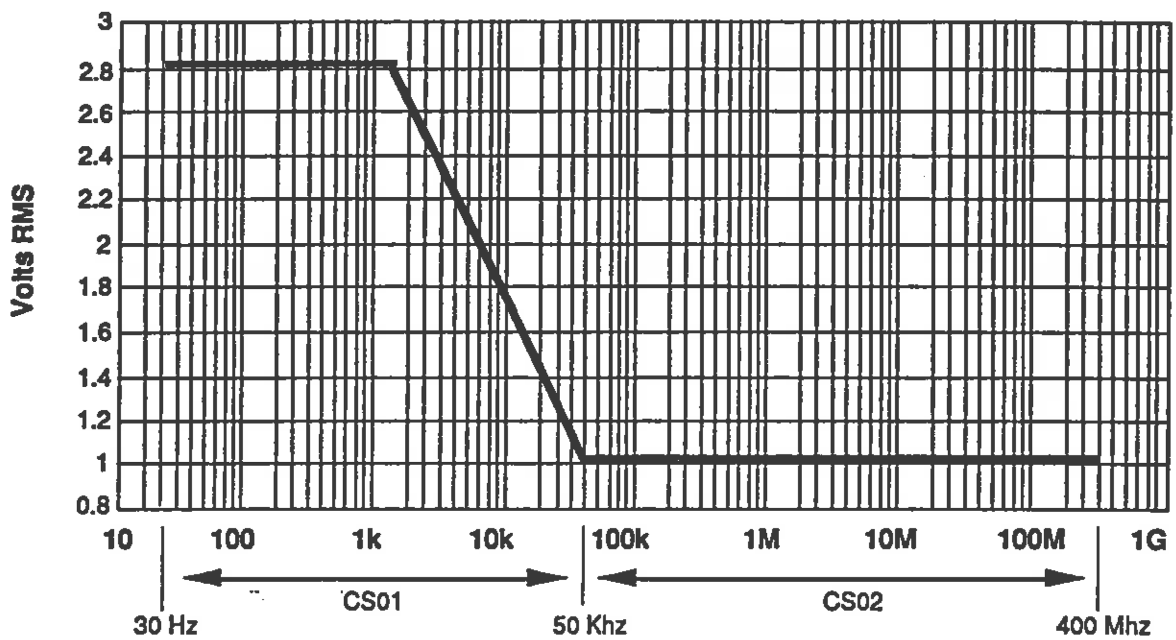


Figure 7.5–2
Limits for CS01 and CS02 on Spacecraft, Subsystems, Components, and Instruments

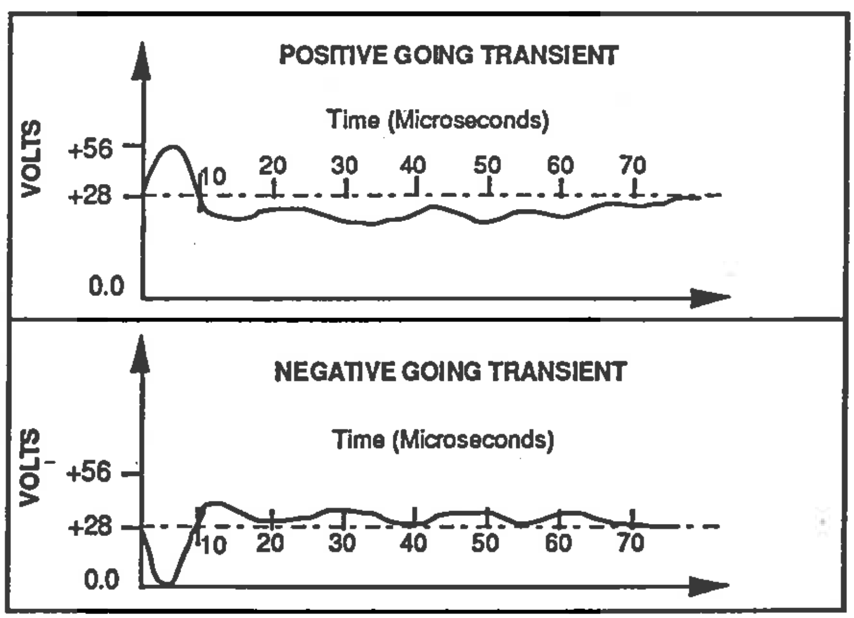


Figure 7.5–3
Limits for CS06 on Spacecraft, Subsystems, Components, and Instruments

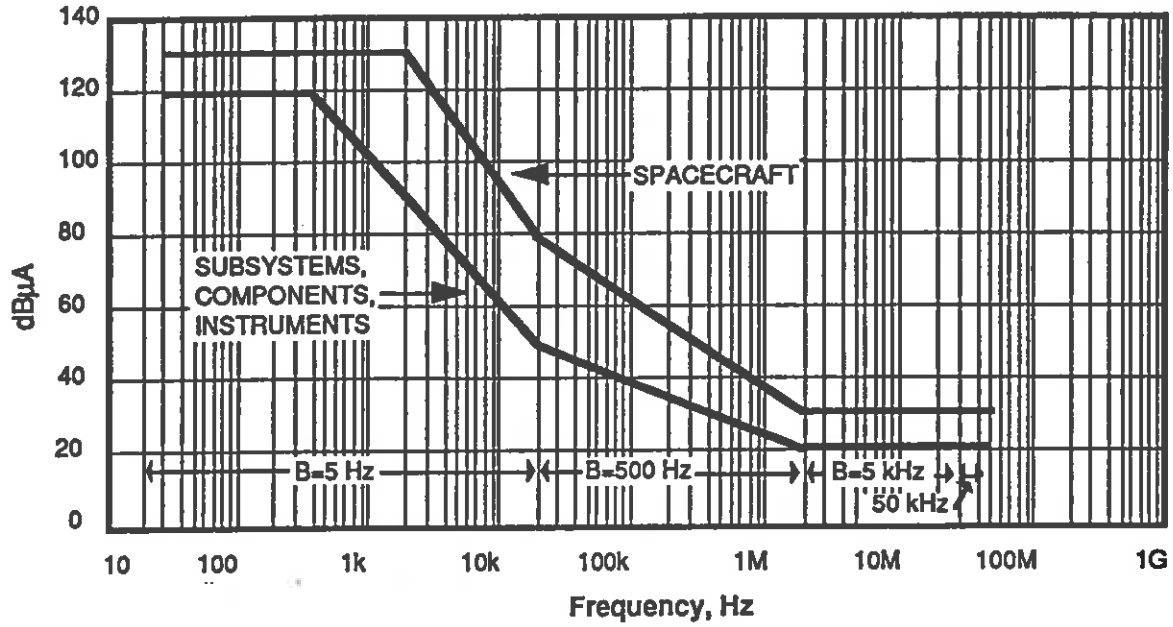


Figure 7.5–4
Narrowband Conducted Emission (CE01) Limits on Observatory Power Lines

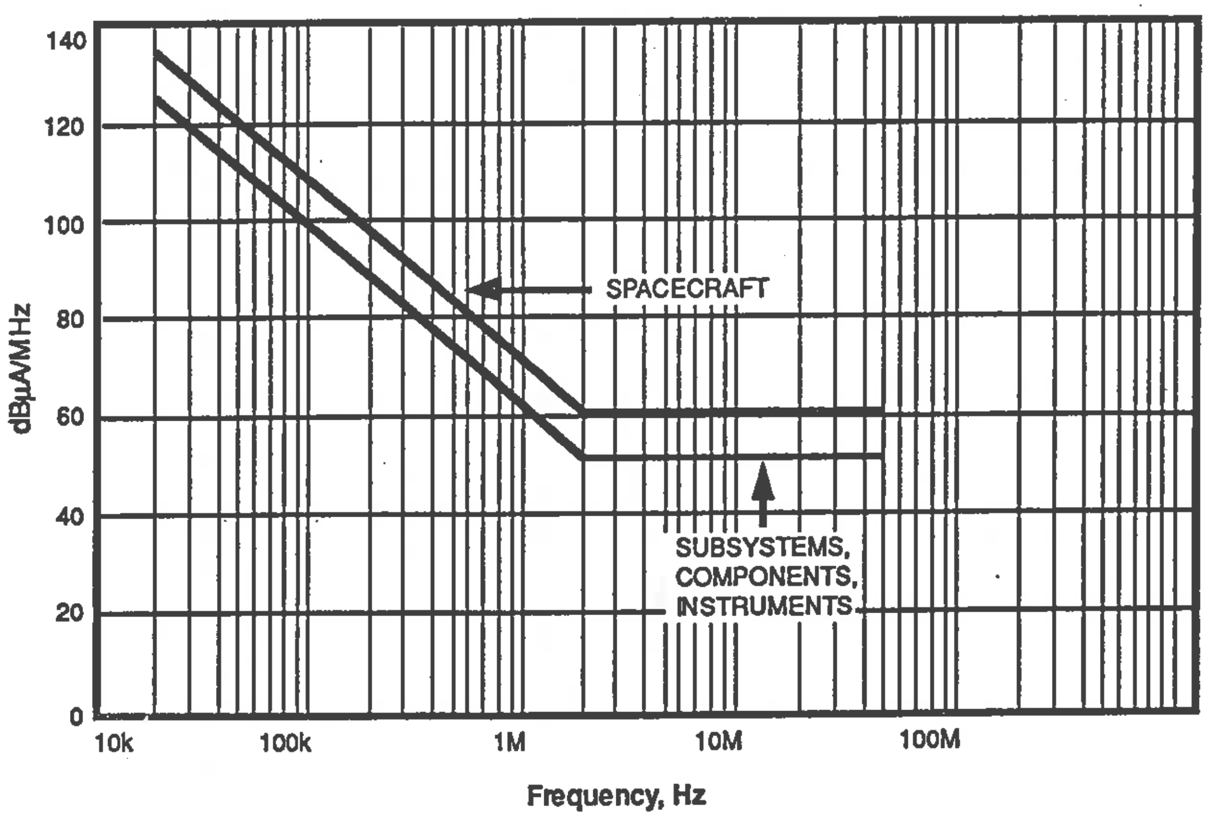


Figure 7.5–5
Broadband Conducted Emission (CE03) Limits on Observatory Power Lines

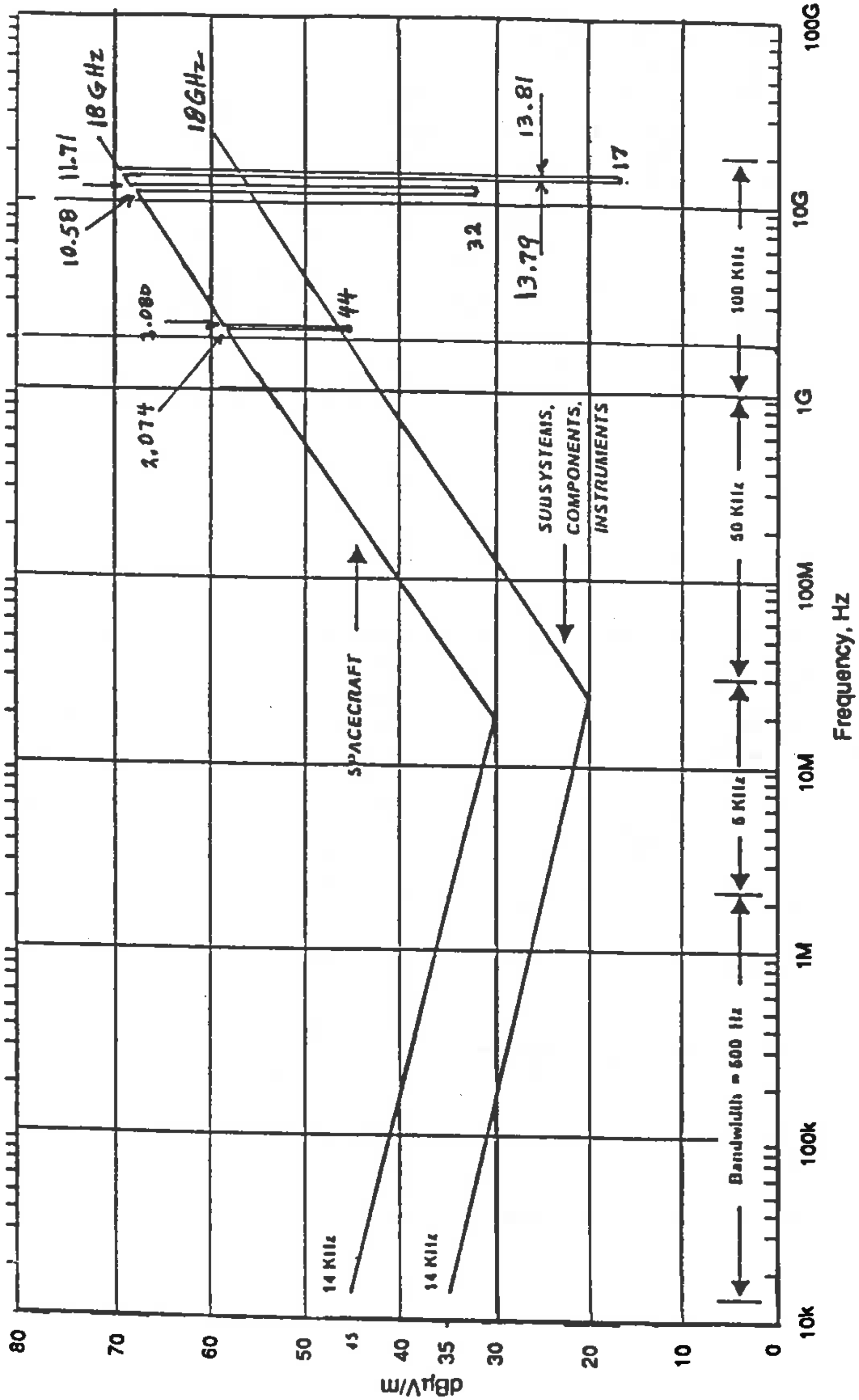


Figure 7.5–6
Unintentional Radiated Narrowband Limits (RE02) for Electric Field Emissions
Produced by Observatory and Observatory Subsystems

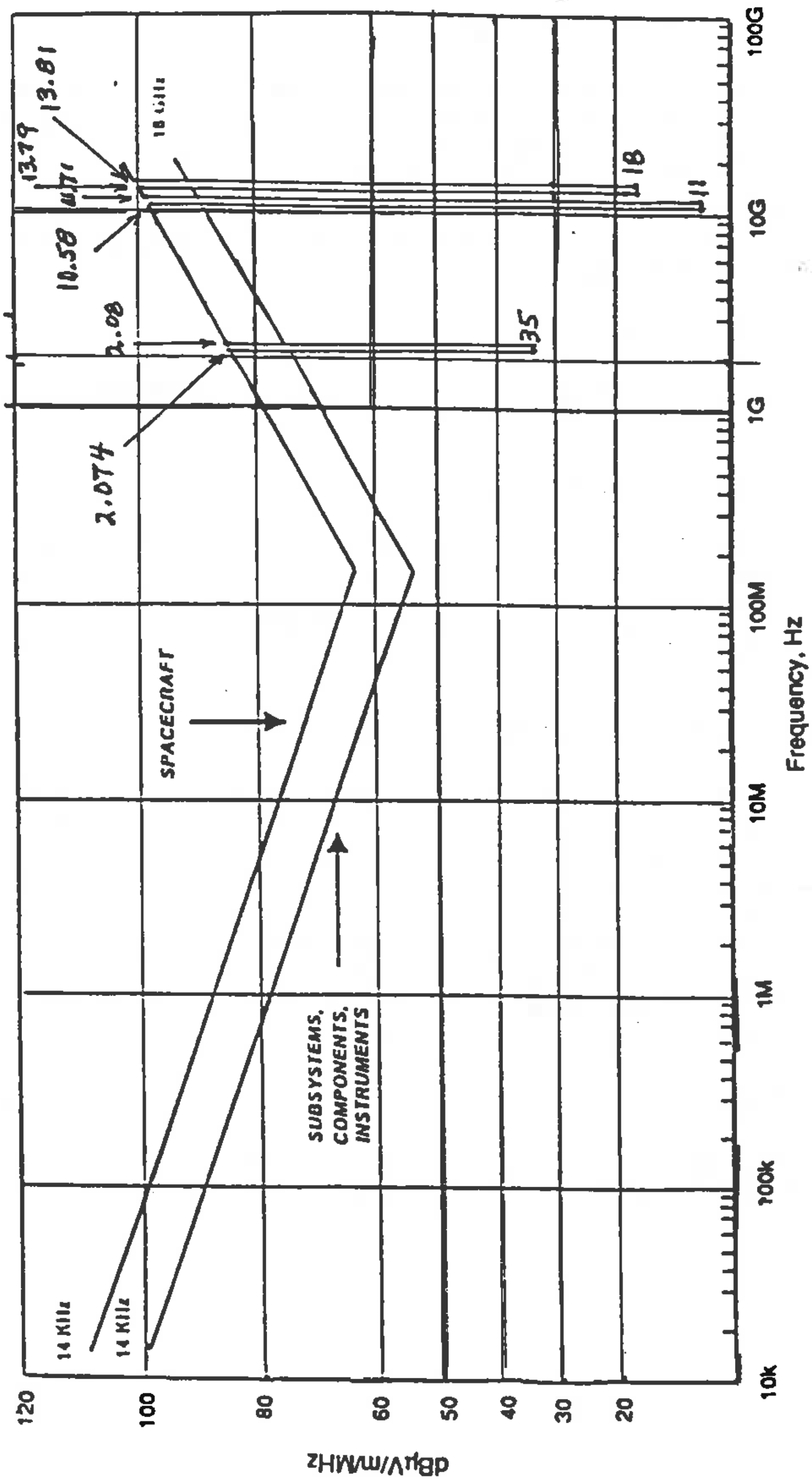


Figure 7.5–7
Unintentional Radiated Broadband Limits (RE02) for Electric Field Emissions
Produced by Observatory and Observatory Subsystems

7.6 Electrostatic Discharge Control

All components sensitive to electrostatic discharge (ESD) damage shall be protected during shipping, handling, and testing with approved protective materials. All containers used for transport of ESD sensitive components shall be marked appropriately. All documents, such as schematics, test procedures, and shipping/handling instructions for ESD sensitive devises shall be marked as ESD sensitive. An ESD program shall be developed in accordance with the MSFC-RQMT-1493 and/or MIL-STD-1686.

7.7 MAGNETIC REQUIREMENTS

This section defines the magnetic requirements for the TRMM spacecraft and the LIS instrument.

7.7.1 Instrument Magnetic Moment

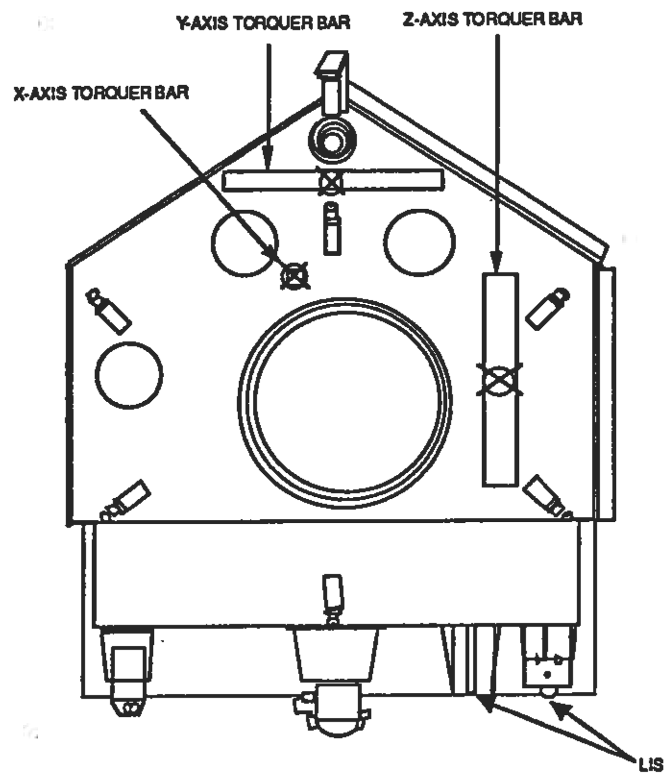
The magnetic flux density of the LIS instrument shall be no more than 100 nanoTesla (1 milligauss) at the observatory three-axis magnetometers as shown in Figure 7.7–1. This requirement shall be interpreted as the free-space magnetic flux density and shall include the permanent field, induced field, and field due to currents in the LIS instrument.

7.7.2 Spacecraft Generated Magnetic Fields

The magnetic torquer bars can generate a magnetic field of up to 350K pole-cm during Initial Orbit Acquisition Mode. When the LIS instrument is operating, a software controlled limit of 225K pole-cm shall be used to reduce spacecraft momentum. When the LIS instrument is not operating, the magnetic field of the torquer bars shall be limited to 350K pole-cm. The LIS instrument shall operate within specification during the operation of the magnetic torquer bars and shall be able to operate after exposure to the higher magnetic fields it could experience during initial orbit acquisition. Locations of the magnetic torquer bars, the magnetometers, the LIS insturment, and the vector lengths are shown in Figure 7.7–1.

7.7.3 Magnetic Test

Each LIS instrument subsystem and/or component which has any degree of sensitivity to magnetic fields should be tested as a stand-alone component and/or as a complete subsystem. (LIS has none.)



Spacecraft Coordinates in mm

3/25/94

INSTRUMENT	X	Y	Z
LIS	691	970	1270
REFERENCE	**X**	**Y**	**Z**
MAGNETOMETER-1	3868	-651	-372
MAGNETOMETER-2	3868	-651	-276
X TORQUER BAR	1060	425	-490
Y TORQUER BAR	412	-188	-693
Z TORQUER BAR	412	693	-109

Vector Length Between LIS Instrument and the Reference Components, in mm.

3/25/94

INSTRUMENT	VECTOR MAG-1	VECTOR MAG-2	VECTOR X TORQ	VECTOR Y TORQ	VECTOR Z TORQ
LIS	3926	3887	1879	2296	1434

Figure 7.7–1
Vector Length

8. COMMAND AND TELEMETRY INTERFACES

This section establishes the general requirements for the command and data handling interfaces between the TRMM spacecraft and the LIS instrument. These interfaces include all command and telemetry requirements being carried over the MIL-STD-1773 Data Bus.

Interface requirements not being carried over the MIL-STD-1773 Data Bus are discussed in Section 7 of this ICD.

8.1 GENERAL

The TRMM spacecraft's Flight Data System (FDS) is the primary data interface to the LIS instrument. Figure 8.1–1 depicts the TRMM spacecraft FDS to the LIS instrument command and telemetry interface block diagram.

Several physical interfaces are used to support this transfer of data. These are:

a. MIL-STD-1773 Interface

b. Discrete signal interfaces.

The MIL-STD-1773 interface supports the transmission of:

a. Commands

- Command packets from the FDS to the LIS instrument
- Periodic time code updates from the FDS to the LIS instrument

b. Telemetry

- Science telemetry packets from the LIS instrument to the FDS
- Housekeeping telemetry packets from the LIS instrument to the FDS

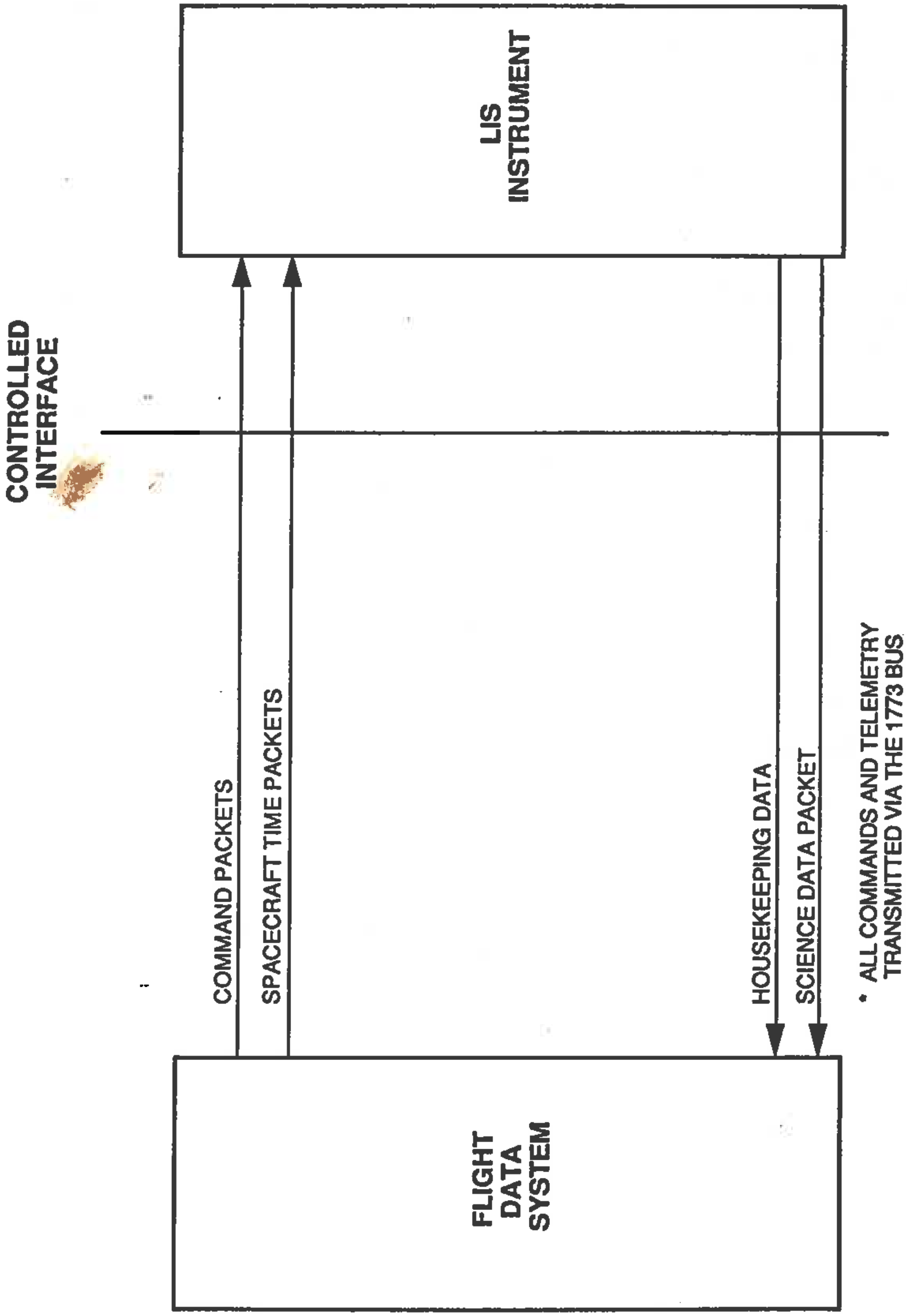


Figure 8.1–1
FDS/LIS Instrument Interface Block Diagram

The MIL-STD-1773 interface is the principle method for transmitting data commands to the LIS instrument, and for receiving science data telemetry from the LIS instrument. The LIS instrument contains one set of MIL-STD-1773 electronics. The RT assignment ID number shall be 2. The FDS operates as the Bus Controller (BC) on this bus. The interface between the TRMM spacecraft's FDS and the LIS instrument is shown in Figure 8.1–2. The bus will consist of two fibers for each side (four fibers total) of the redundant bus. The optical characteristics are listed in Table 8.1–1. Table 8.1–2 lists the LIS 1773 optical bus connector assignments.

Table 8.1–1
MIL-STD-1773 Terminal Optical Characteristics

ITEM	DESCRIPTION
Optical Connector	SMA 905
Optical wavelength	850 nm
Fiber size to be used	100/140 μm
Coding	Manchester II Bi-phase
Receiver optical sensitivity (with 100/140 micron fiber)	-33 dBm (0.5 μW) minimum -30 dBm (1.0 μW) typical
Transmitter optical output power (with 100/140 micron fiber)	-9.4 dBm (116 μW) minimum -8.4 dBm (145 μW) typical

Discrete signals are used to provide:

a. Spacecraft timing signal (1 Hz Clock)

b. Analog telemetry to measure temperature of the LIS

The discrete signals are discussed in detail in Section 7 of this ICD.

Unless otherwise noted, all digital data (commands and telemetry) shall be in the following format:

a. The digital data shall be in 2's complement with a 1 being true.

b. For serial data, the most significant bit (MSB) shall be sent first. The bit numbering shall be MSB labeled BIT 1 and the least significant bit (LSB) labeled BIT 16 for a 16-bit word (BIT 1 and BIT 8, respectively, for an 8-bit byte).

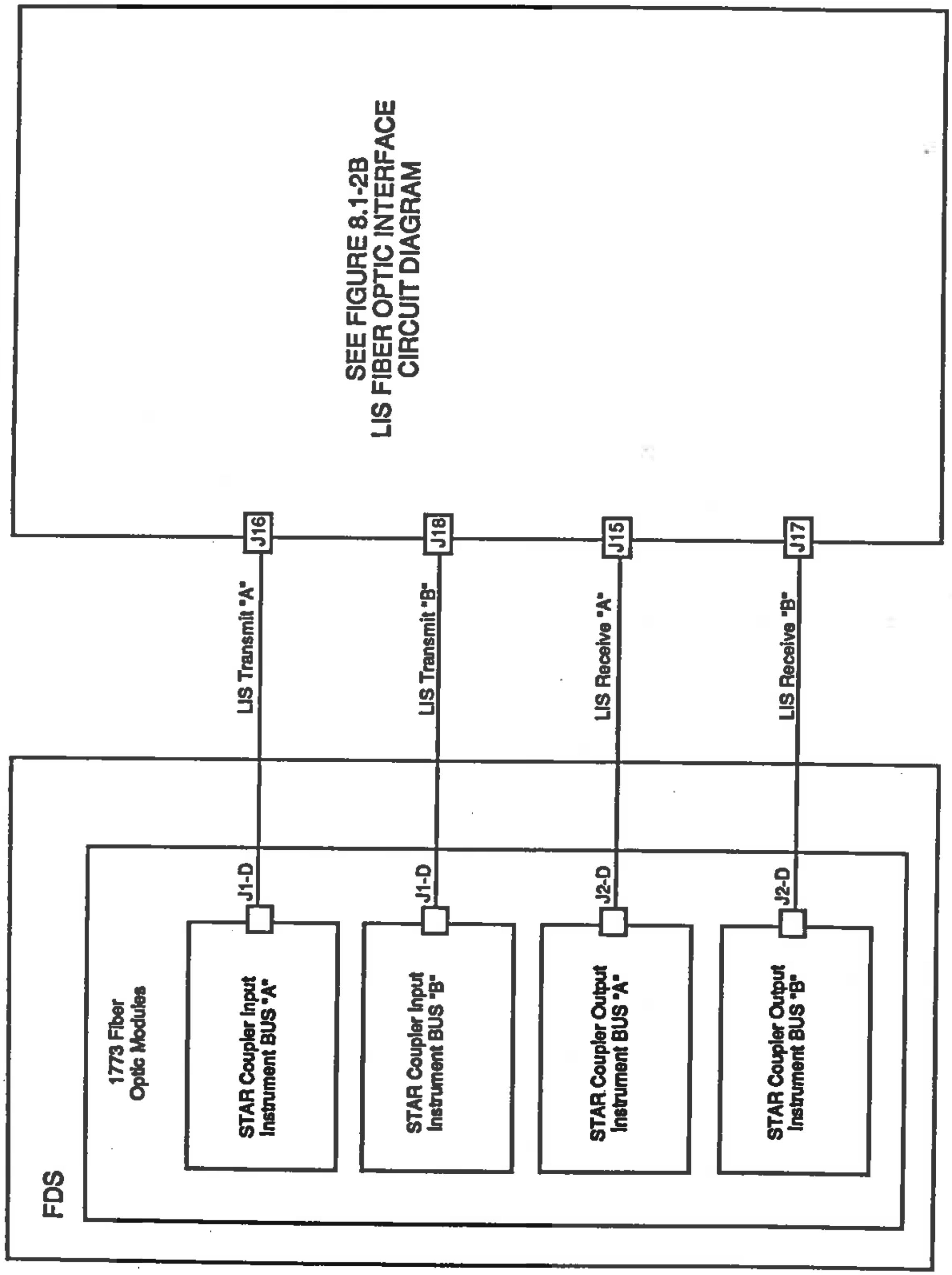


Figure 8.1–2A
FDS/LIS Instrument Optical Bus Interface

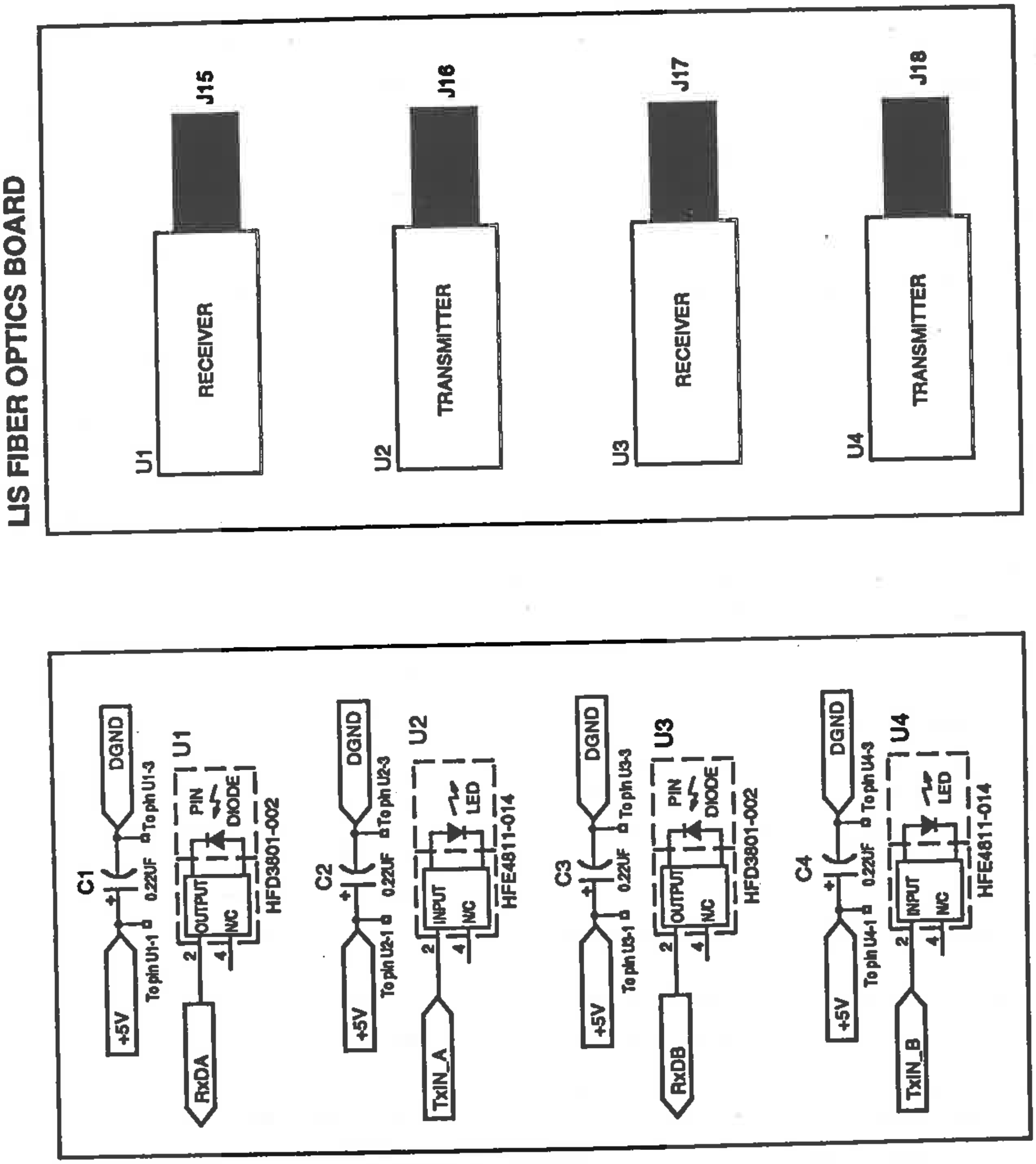


Figure 8.1–2B
FDS/LIS Instrument Optical Bus Interface

Table 8.1–2
LIS 1773 Optical Bus Connectors (Preliminary)

LIS/TRMM 1773 BUS INTERFACE CONNECTOR PIN ASSIGNMENTS J15 1553/1773 RECEIVER SMA CONNECTOR P15 SMA SERIES FIBER OPTICS CABLE PLUG PART# --- AMP 905-150-5001		
PIN#	SIGNAL FUNCTION	REMARKS
1	1773 BUS-A INPUT	

LIS/TRMM 1773 BUS INTERFACE CONNECTOR PIN ASSIGNMENTS J16 1553/1773 RECEIVER SMA CONNECTOR P16 SMA SERIES FIBER OPTICS CABLE PLUG PART# --- AMP 905-150-5001		
PIN#	SIGNAL FUNCTION	REMARKS
1	1773 BUS-A OUTPUT	

LIS/TRMM 1773 BUS INTERFACE CONNECTOR PIN ASSIGNMENTS J17 1553/1773 RECEIVER SMA CONNECTOR P17 SMA SERIES FIBER OPTICS CABLE PLUG PART# --- AMP 905-150-5001		
PIN#	SIGNAL FUNCTION	REMARKS
1	1773 BUS-B INPUT	

LIS/TRMM 1773 BUS INTERFACE CONNECTOR PIN ASSIGNMENTS J18 1553/1773 RECEIVER SMA CONNECTOR P18 SMA SERIES FIBER OPTICS CABLE PLUG PART# --- AMP 905-150-5001		
PIN#	SIGNAL FUNCTION	REMARKS
1	1773 BUS-B OUTPUT	

8.2 DATA MANAGEMENT INTERFACES

The Flight Data System (FDS) is a "Packet" based data system, i.e. all telemetry sent to the ground is sent in the form of "packets," and all commands received from the ground are formatted as "packets." The format of these "packets" conforms to the Consultative Committee for Space Data Systems (CCSDS) Recommendations. This section addresses the general requirements for the telemetry interfaces between the TRMM spacecraft and the LIS instrument.

8.2.1 Telemetry Packet Descriptions

The LIS instrument provides a variety of types of telemetry packets that include science, housekeeping, and diagnostic telemetry packets.

The FDS communication with the LIS instrument is described in this document as several layers of communication, which is depicted in Figure 8.2–1. At the physical layer, the FDS uses fiber optics to communicate with the LIS instrument.

The protocol of the MIL-STD-1773 specifies how data is to be communicated in bus messages (with a maximum transfer size of 64 octets for each subaddress). Above this layer, the FDS to LIS instrument communications is controlled by a "Packet Communications" protocol that allows packets of a size of up to 1024 octets to be transmitted over the MIL-STD-1773 bus.

The FDS supports the acquisition of science, housekeeping, and diagnostic packets of telemetry.

8.2.1.1 Science/Diagnostic Packet Transfers

The FDS shall use the following protocol to perform packet reads of up to 1024 octets from the LIS instrument:

a. Read subaddress #25 to obtain a TRANSMIT_REQUEST word. This single word transfer shall specify whether the RT has data to transmit.

   - If the TRANSMIT_REQUEST word is zero, or has not changed in value since the last read, the FDS will take no further action during this cycle.

   - If the TRANSMIT_REQUEST word is non-zero, and has changed in value since the last read, the FDS shall perform 16 reads of 64 octets (32 MIL-STD-1773 words) each. The reads shall begin at subaddress #1 and each subsequent read will be from the next higher subaddress number. (i.e., the FDS shall read subaddresses 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, and 16.)

In the event of MIL-STD-1773 bus communication errors, the FDS may elect to request a re-transmission of any particular subaddress from the secondary bus. In the event that the retry also fails, the full packet of up to 1024 octets shall be discarded.

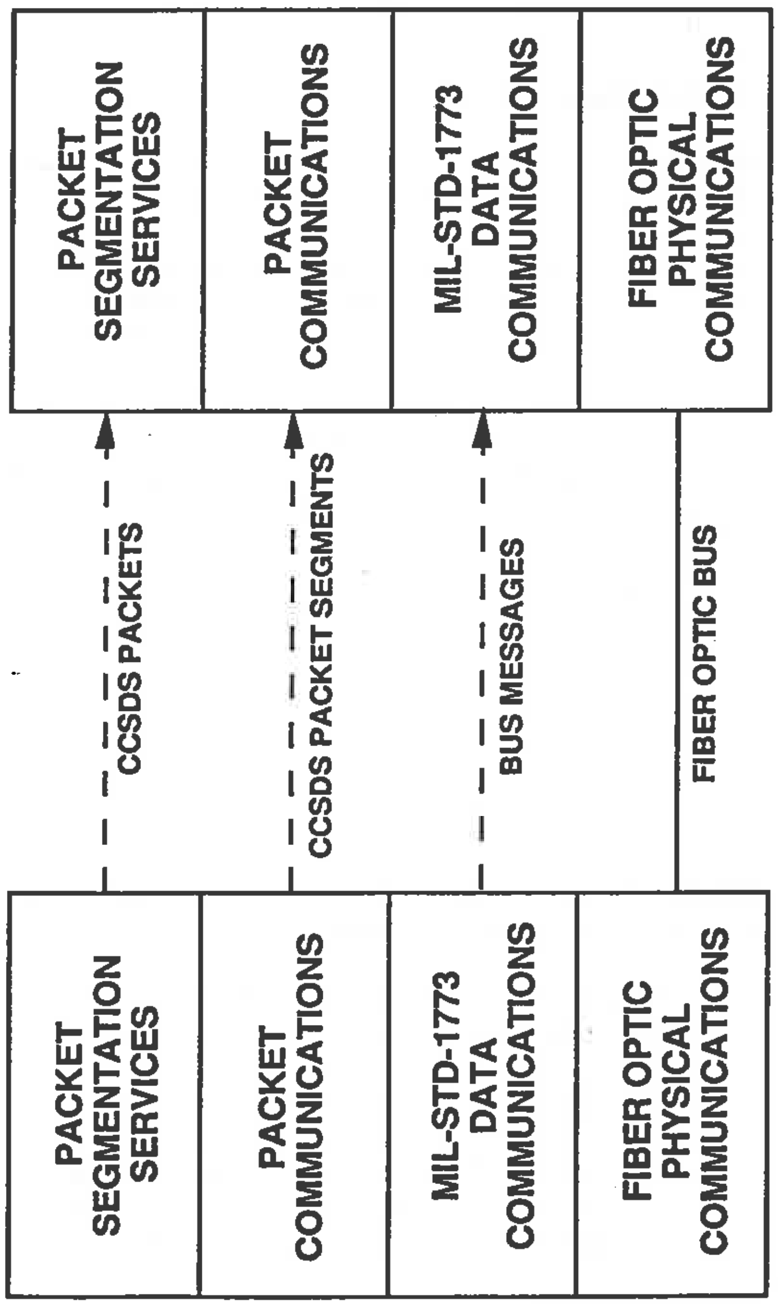


Figure 8.2–1
Telemetry Communication Layers

The data read in these MIL-STD-1773 transfers shall be formatted as a single CCSDS packet. The telemetry packets shall include a primary header and a secondary header as described in Section 8.2.2. All data in the CCSDS header is to be sent most significant bit first (on sixteen bit boundaries).

After the requested number of subaddresses have been read, the FDS shall read one word from subaddress #29 to signal the completion of the packet input cycle.

The time between when the TRANSMIT_REQUEST (subaddress #25) is initially read to the time of the FDS's read to signify end of packet read (subaddress #29), shall be less than 970 ms.

Data packet type is determined by the unique application ID(s) assigned to each instrument.

During observatory Mission Mode, science data packets shall be recorded and downlinked in playback data during times of contact.

8.2.1.2 Housekeeping Packet Transfers

The FDS shall use a similar protocol as that used for science packets except the maximum size of a housekeeping packet is restricted to 64 octets including the header.

a. Read subaddress #28 to obtain a TRANSMIT_REQUEST word. This single word transfer shall specify whether the LIS instrument RT has data to transmit.

   - If the TRANSMIT_REQUEST word is zero, or has not changed in value since the last read, the FDS will take no further action during this cycle.

   - If the TRANSMIT_REQUEST word is non-zero and has changed in value since the last read, the FDS shall perform one read of 64 octets (32 MIL-STD-1773 words) from subaddress #17.

In the event of MIL-STD-1773 bus communication errors, the FDS may elect to request a re-transmission of any particular subaddress from the secondary bus. In the event that the retry also fails, the full packet of up to 64 octets shall be discarded.

The data read in these MIL-STD-1773 transfers shall be formatted as a single CCSDS packet. The telemetry packets shall include a primary header and a secondary header as described in Section 8.2.2. All data in the CCSDS header is to be sent most significant bit first (on sixteen bit boundaries).

After the requested number of subaddresses have been read, the FDS shall read one word from subaddress #27 to signal the completion of the packet input cycle. The time between reading this word and the next TRANSMIT_REQUEST shall be a minimum of 20 ms.

8.2.1.3 Science/Diagnostic Data Synchronization

The LIS instrument shall run asynchronously with the FDS. The FDS will allocate sufficient bus bandwidth to slightly "oversample" the LIS instrument.

The FDS will perform one science data packet transfer per second. This will provide an "instantaneous" data rate of 8 kbps from the LIS instrument to the FDS. The orbit average data rate will be constrained by the amount of data storage memory that can be used by the LIS instrument to hold telemetry data. Sufficient memory shall be provided to store two orbits of LIS instrument data acquired at the orbit average data rate of 8 kbps. In the event that the LIS instrument sends more data than can be stored in its memory allocation, the most recently received data may not be stored or transferred.

8.2.1.4 Housekeeping Data Synchronization

The FDS shall perform one housekeeping packet transfer read per second. The LIS instrument is responsible for delivering no more than 1 kbps to the TRMM spacecraft.

8.2.2 Telemetry Formats

All data transferred in Packets Reads shall be transmitted as CCSDS telemetry packets. The following fields are included in the telemetry packets:

a. Version number - As per CCSDS recommendations. It will have a value of all zeros.

b. Type - As per CCSDS Telecommand recommendations. This bit is used to distinguish telecommand packets from telemetry packets. For telemetry packets, this bit is set to zero.

c. Secondary Header Flag - For telemetry packets that have a secondary header, this bit shall be set.

d. Application Process ID - This is the primary method for identifying packets. For the LIS instrument, the following application IDs may be used in the prescribed manner:

- 32h - Reserved for LIS housekeeping data
- 3Dh - Reserved for LIS science operations

e. Segment Flags - All LIS packets are unsegmented so this two bit field should equal 11.

f. Source Sequence Count - As per CCSDS this is a 14 bit counter maintained for each application ID that increments for each packet sent with the specified application ID. The sequence count of the first packet following power-up shall be zero (0).

g. Packet Length - Formatted as per CCSDS Telemetry recommendations. (It is the length of the entire packet less the length of the primary header (6) less one (1).) The length of the science packet (including the packet header) directly transmitted over the MIL-STD-1773 bus will be restricted to no more than 1024 octets and it will be an even number of octets. The length of the housekeeping packets must be less than or equal to 64 octets.

h. Secondary Header - All LIS segments of packets shall have a time code field in a secondary header. The format of the time code is shown in Section 8.3.2

i. Application Data - The Application Data field contains application data.

Figure 8.2–2 shows the telemetry packet format.

8.2.3 Telemetry Data Rates

The data rates can be separated into data storage rates and real-time rates.

8.2.3.1 Data Storage Rates

The FDS shall allocate to the LIS instrument the following data storage rates:

a. 8 kbps of science/diagnostic data and 100 bps of housekeeping data over two orbits in observatory Mission Mode

b. 8 kbps of science/diagnostic data and 100 bps of housekeeping data over two orbits in observatory Engineering Mode

Once the allocated memory is filled, all additional packets may be lost.

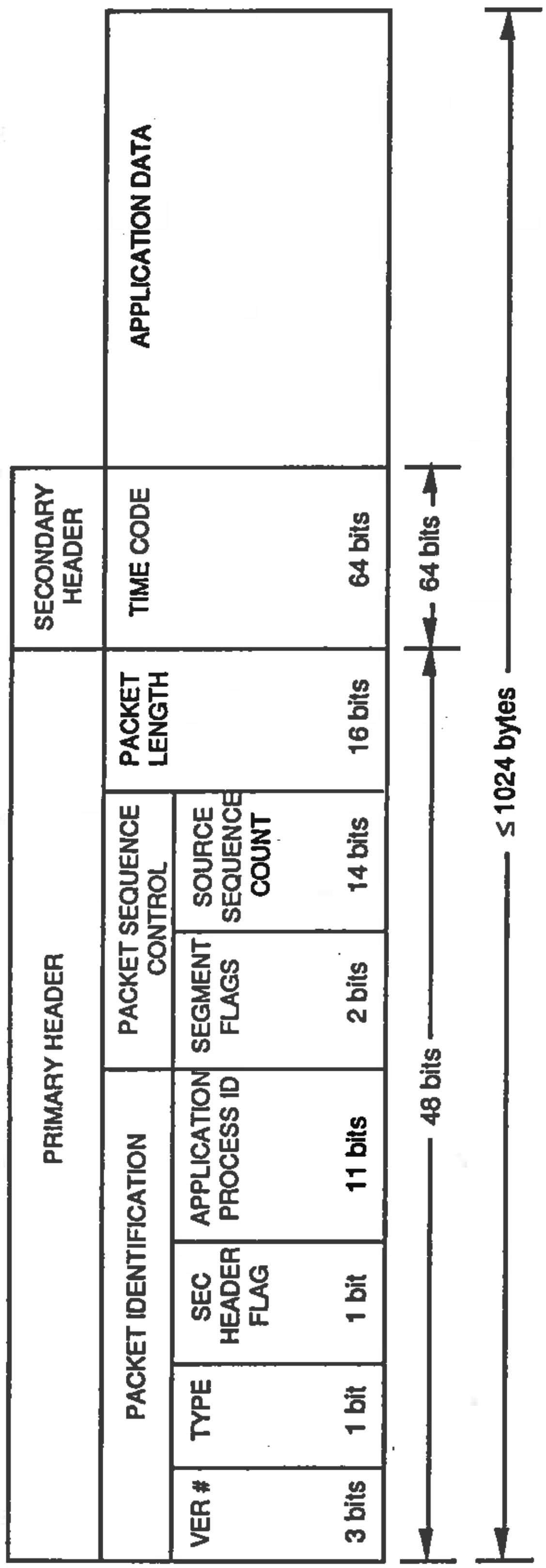


Figure 8.2–2
Telemetry Format

8.2.3.2 Real-Time Rates

The FDS shall allocate to the LIS instrument the following real-time rates:

a. 1 kbps of housekeeping in observatory Mission Mode

b. 1 kbps of housekeeping data in observatory Engineering Mode.

8.2.4 Telemetry List

Table 8.2–1 lists and defines the telemetry points required for the LIS instrument.

Table 8.2–1
LIS Instrument Telemetry List

Channel No.	Measurement Name
0	Primary Heater Temperature
1	Secondary Heater Temperature
2	Spare
3	Sensor Head Assembly Temperature
4	Optics Filter Temperature
5	Focal Plane Array Temperature
6	Controller Board Temperature
7	Power Converter Temperature
8	Power Converter Input Current
9	-15.0 Volt Analog Circuit Power
10	+15.0 Volt Analog Circuit Power
11	-5.2 Volt Analog Circuit Power
12	+5.2 Volt Analog Circuit Power
13	+5.0 Volt Digital Circuit Power
14	Analog Ground Reference
15	Precision Reference Voltage

The LIS instrument will monitor its critical parameters and include them as part of the housekeeping data packet when the LIS instrument is powered. All parameters in the LIS housekeeping and start-up diagnostic packets which are greater than 8 bits are required to be aligned on the 16 bit word boundries within the packet.

8.3 TIME INTERFACES

This section addresses the general requirements for the time code interfaces between the TRMM spacecraft and the LIS instrument.

8.3.1 Time Codes

The TRMM FDS shall maintain a time code, which can be correlated to within 1 ms of Universal Time (UT). The FDS's implementation uses two separate time codes:

a. the spacecraft time

b. UT Correlation Factor (UTCF).

8.3.1.1 Spacecraft Time

The spacecraft time is used for all LIS instrument and data system operations and is not correlated to UT. Spacecraft time is maintained by the FDS and distributed to the LIS instrument for time stamping of instrument packets. Only coarse time (seconds) is distributed to the LIS instrument, prior to each 1 Hertz discrete signal. It is the responsibility of the LIS instrument to maintain the fine time (subseconds) used in the time stamping of instrument packets.

8.3.1.2 UT Correlation Factor

The UT Correlation Factor (UTCF) is used to correlate spacecraft time to UT. The UTCF shall be maintained by ground operations, such that the sum of the spacecraft time and this UTCF shall always be within 1 ms of UT. The UTCF is a static variable stored on-board the FDS and maintained by ground operations. This UTCF is not available to the LIS instrument on-board but will be returned in ancillary telemetry for data reduction on the ground. The LIS instrument can correlate its packets to UT time by using the packet time stamp in conjunction with the UTCF.

8.3.2 Time Code Format

The format of the spacecraft time and the UTCF are identical. This format has two major subfields:

a. Seconds

b. Subseconds.

The time code is represented by a 64 bit number. The 32 most significant bits represent the "seconds" and the least significant 32 bits represent "subseconds". (e.g. the subseconds binary value 1000 0000 0000 0000 0000 0000 0000 0000 represents 1/2 second, the subseconds binary value 0100 0000 0000 0000 0000 0000 0000 0000 represents 1/4 second, etc). The time code format is per CCSDS standards (CCSDS Time Code 301.0-B-2, Section 2.2.1 T-Field).

Figure 8.3–1 shows the time code format.

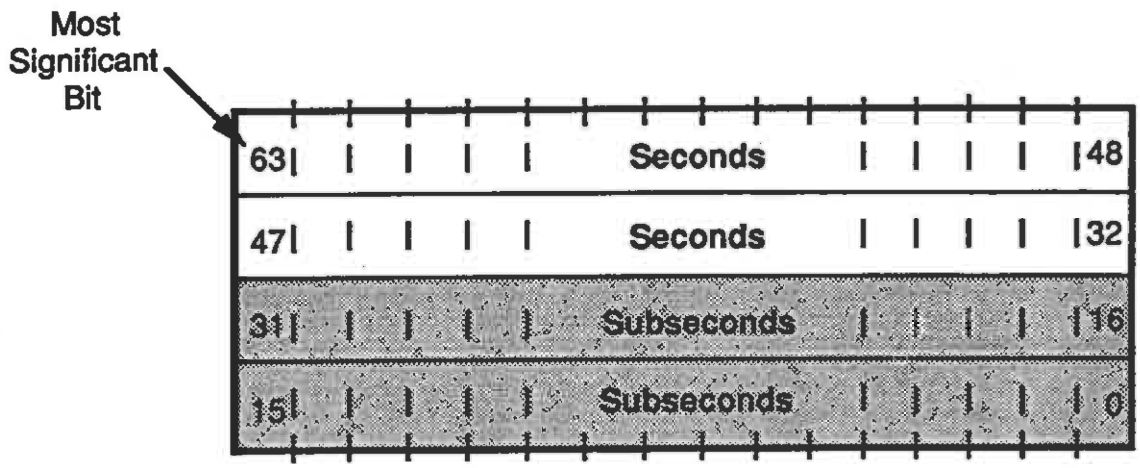


Figure 8.3–1
Time Code Format

8.3.3 Time Code Transmission

Once per second the FDS shall deliver the spacecraft time code update to the LIS instrument. The meaning of the time code in this packet is the spacecraft time associated with the next 1 Hertz clock sent to the LIS instrument.

The time code update will be formatted as a CCSDS command packet. The FDS shall write this 16 octet packet to subaddress #6. The command application ID for the time code update packet shall be 64h. The FDS shall deliver the packet between 100 and 900 ms prior to the next 1 Hertz signal. Figure 8.3–2 shows the format of the time code update packets.

Word No.	Value (hex)	Description		
Word #1	1864	Primary Header:	Packet Identification	
Word #2	C000		Packet Sequence Control	
Word #3	0009		Packet Length	
Word #4	0100	Secondary Header:	Function Code	
Word #5	xxxx	Application Data:	Seconds	(Most sig 16 bits)
Word #6	xxxx			(Least sig 16 bits)
Word #7	0000		Subseconds	(Most sig 16 bits)
Word #8	0000		(always 0)	(Least sig 16 bits)

Figure 8.3–2
Format of Time Code Update Packet

8.4 COMMAND DISTRIBUTION AND STORAGE

This section addresses the general requirements for the command interfaces between the TRMM spacecraft and the LIS instrument.

8.4.1 Command Constraints

The following command constraints shall be maintained for all TRMM commands:

a. Lock and key commands shall be used for any critical functions.

b. No toggle or step commands shall be used for normal operational commands.

c. Positive telemetry verification will be provided for all ground generated commands.

d. Any commandable bi-state condition (ON/OFF, OPEN/CLOSE) within a command packet shall not be implemented using one bit, but instead shall be implemented using two bits, one for each state.

8.4.2 Command Packet Description

The FDS shall deliver command packets to the LIS instrument via the MIL-STD-1773 interface. These packets conform to CCSDS packet specifications.

All commands processed by the FDS are received from the ground (or stored command) in the form of CCSDS command packets. The FDS relies on the combination of packet application ID and function codes to route the data to its destination.

When sending a packet to the LIS instrument, the full CCSDS command will be sent. The following types of commands can be sent:

a. short commands (64 octets)

8.4.2.1 Short Command Packet Transfers

The FDS shall use the following protocol to write short commands (up to 64 octets) to the LIS instrument:

a. Write to subaddress #5 the short command (Note the transfer is a fixed 64 octets transfer. If a short command is less than 64 octets, random fill shall be concatenated and written to satisfy the 64 octets transfer).

8.4.3 Command Timing

All commands, including ground commands and stored commands sent to the LIS instrument, shall be separated by at least 32 ms. The time between any command and the time code update shall be greater than 8 ms. The maximum command rate to the LIS instrument shall be 20 commands per second.

8.4.4 Command Formats

The LIS instrument command packet format shall conform to Consultative Committee on Space Data Systems (CCSDS) Telecommands Recommendations. The format of the packet is as follows:

a. Version number - As per CCSDS recommendations. It will have a value of all zeros.

b. Type - As per CCSDS Telecommand recommendations. This bit is used to distinguish telecommand packets from telemetry packets. For command packets, this bit is set to "1".

c. Secondary Header Flag - All telecommand packets include a secondary header. This bit shall be set to "1".

d. Application Process ID - This field in combination with the function code field is used by the FDS to route data to the LIS instrument. (The FDS translates this into a MIL-STD-1773 RT address and subaddress.) For the LIS instrument, the following application IDs may be used in the prescribed manner:

   - 71h - Reserved for LIS short commands

e. Segment Flags - No Segmentation is supported. These bits will be set to "11" (base 2).

f. Source Sequence Count - As per CCSDS this is a 14 bit counter maintained for each application ID that increments for each packet sent with the specified application ID. (Warning: Ground software may not properly increment this sequence counter. In the FDS this field is ignored by the flight software. The command uplink protocol ensures in-sequence delivery.)

g. Packet Length - Formatted as per CCSDS Telecommand recommendations. For the LIS instrument the length of the packet will be restricted to no more than 250 octets and it will be an even number of octets.

h. Secondary Header - The secondary header consists of the following fields:

   - Zero(1): This bit is set to zero to indicate that the secondary header is non-CCSDS defined.

   - Function Code(7): This field is used to identify an individual command associated with an application ID. The combination of function code and application ID determines command routing.

   - Checksum(8): These bits are used for an exclusive OR checksum of the full command. When all the bytes in the command are exclusive OR-ed together, the resulting value will be 1111 1111(base 2). This checksum is generated by the ground software and is verified by the FDS software prior to the delivery of the command to the instrument. The instrument is not required to do anything with this checksum.

i. Application Data - The application data field contains application data.

This format is shown in Figure 8.4–1.

8.4.5 Stored Commands

The FDS shall provide a stored command capability for autonomous operation of the TRMM spacecraft and the TRMM instruments. The FDS software shall reserve sufficient stored command memory for the operation of the LIS instrument.

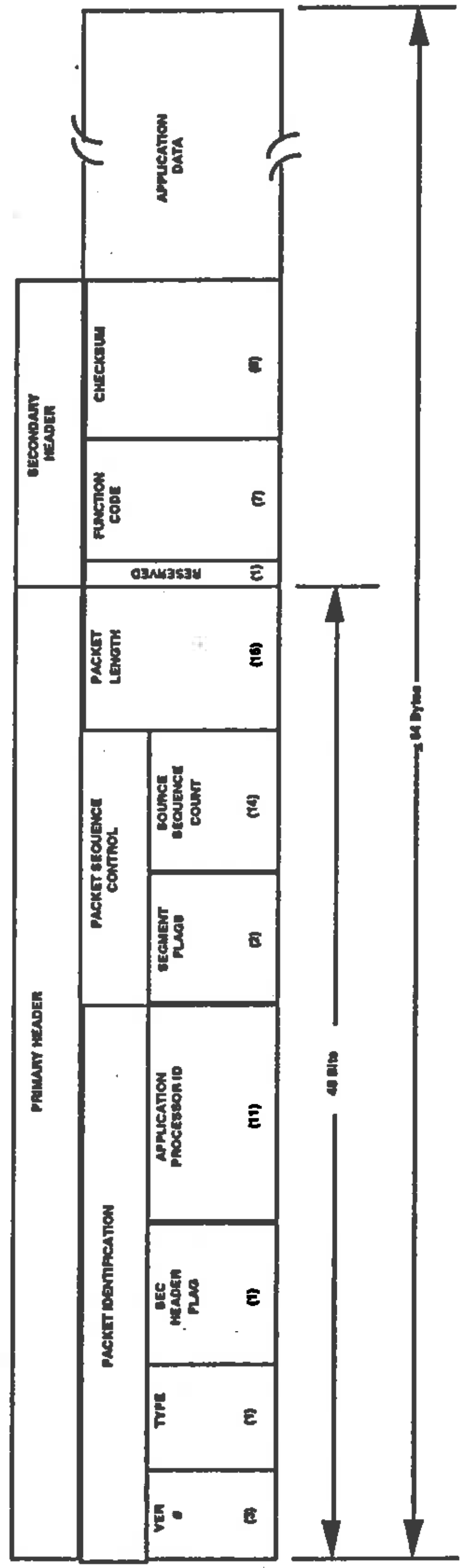


Figure 8.4–1
Command Packet Format

The LIS commanding requirements (including number of commands required to be sent per day) is to be determined as part of the operational agreements between LIS and the Flight Operations Team (FOT).

8.4.6 Command List

Table 8.4–1 lists and defines the commands required for operations of the LIS instrument.

Table 8.4–1
LIS Instrument Command List

8/7/95

Mnemonic	Bit Pattern	Name	Description
SC_CLKA	0000 0021	SELECT SPACECRAFT CLOCK A	Upon receipt of this ground command the flight software will send a command to the flight hardware which will select the A Channel 1 Hz signal as the source for the Timemark Interrupt. The software will set the 1 Hz Clock Status Bits to a value of 01.
SC_CLKB	0000 0022	SELECT SPACECRAFT CLOCK B	Upon receipt of this ground command the flight software will send a command to the flight hardware which will select the B Channel 1 Hz signal as the source for the Timemark Interrupt. The software will set the 1 Hz Clock Status Bits to a value of 10.
SC_CLK	0000 0024	SELECT SPACECRAFT CLOCK A "OR" B Power-up Configuration	Upon receipt of this ground command the flight software will send a command to the flight hardware which will select both 1 Hz signals OR'd together as the source for the Timemark Interrupt. The software will set the 1 Hz Clock Status Bits to a value of 11.
BG_ON_6	1111 0011	BACKGROUND SEND MODE ON (6kbps)	This command will cause the flight software to enter the Background Send On Mode. Background data will be placed into the science data packet when space is available. Science packets will always be 512 words (1024 octets). Packets with only Background data will be sent every two seconds to provide an orbital average data rate of 6kbps.
BG_ON_8	1111 0012	BACKGROUND SEND MODE ON (8kbps) (Not used with OTD)	This command will cause the flight software to enter the Background Send On Mode. Background data will be placed into the science data packet when space is available. Science packets will always be 512 words (1024 octets). Packets with only Background data will be sent every second to provide an orbital average data rate of 8kbps.

Table 8.4–1
LIS Instrument Command List (continued)

8/7/95

Mnemonic	Bit Pattern	Name	Description
BG_OFF	2222	BACKGROUND SEND MODE OFF	This command will cause the flight software to enter the Background Send Off Mode. Background data will not be placed into the science packet. Packets will be of variable length. Minimum packet size will be 32 words (64 octets).
THADJ	3333	THRESHOLD ADJUSTMENT	This command will include 16 threshold values (packed into eight words). Upon receipt of this command the flight software will upload the new values to the RTEP threshold memory. The flight software will then read the uploaded values from the RTEP to verify upload and set the appropriate status bits.
RSTHT	4444	RESET HEATERS	Upon receipt of this command the flight software will send a Reset Heaters command to the Heater Controller.
ST_EN	5555	SELF TEST ENABLE	This command will cause the flight software to enter the Self Test Mode. This flight software will initiate the sending of three pulses to an optical transmitter located in the Sensor Head Assembly. After three pulses have been sent the flight software will take itself out of Self Test Mode. Science data will be gathered as during normal operations. The flight software will set the appropriated status bits to indicate which packets contain Self Test data.
HTRS_ON	6666	TURN BOTH HEATERS ON	This command will cause the flight software to send a command to turn the Primary Heater on followed by a command to turn the Secondary Heater on. When both heaters are on the software will monitor only the Primary Heater temperature and will turn both heaters off if this value exceeds the set limit(s).
AUTO_M2	7777	HEATER SELECT MODE 2	This command will cause the flight software to monitor the filter heater temperature and test the measurement against defined upper and lower limits. If the Primary heater is active and the measurement is out of the defined limits, the flight software will issue commands to the Heater Controller to disable the Primary heater and activate the Secondary heater, and set the appropriate status bits. If the Secondary Heater is active and the measurement is out of the defined limits, the flight software will issue the command to the Heater Controller to disable the Secondary Heater and set the Both Heaters Failed Flag staus bit.
AUTO_M1	8888	HEATER AUTO SELECT MODE 1	This command will cause the flight software to monitor the filter heater temperature and test only against an upper extreme limit. Heater switching and failure notification are the same as listed for HEATER AUTO SELECT MODE 2.

Table 8.4–1
LIS Instrument Command List (continued)

8/7/95

Mnemonic	Bit Pattern	Name	Description
WD_EN	9999	WATCHDOG ENABLE	This command will cause the flight software to enable the Watchdog Timer.
WD_DIS	AAAA	WATCHDOG DISABLE	This command will cause the flight software to disable the Watchdog Timer.
PHT_ON	BBBB	PRIMARY HEATER ON	This command will cause the flight software to send the Reset Heaters command followed by the enable Primary Heater command to the Heater Controller.
SHT_ON	CCCC	SECONDARY HEATER ON	This command will cause the flight software to send the Reset Heaters command followed by the enable Secondary Heater command to the Heater Controller.
AUTODIS	DDDD	HEATER AUTO SELECT DISABLE	This command will cause the MPR/C to stop monitoring the heater filter temperatures. The MPR/C will be unable to switch heaters. All heater control must be initiated by ground command.
G_WDT	EEEE	GENERATE WATCHDOG TIMEOUT	This command sends the software into a section of code that does not allow it to return to the Main Loop. After 1.5 seconds the Watchdog (if enabled) will timeout and reset the MPR/C. If the Watchdog is not enabled a system reset will be required to reset the MPR/C.
F_FIFO	FFFF	FLUSH FIFO (not used with OTD)	This command will cause the software to issue a command to RTEP digital board to reset the FIFO and FIFO count. The software will also clear all events in the event data stack.

Comments

1) Mnemonics are limited to seven letters to allow them to be used as labels in the flight software.
2) All command bit patterns are verified before executing and returned in the following packets.

8.5 OBSERVATORY ANCILLARY DATA AND ORBIT DETERMINATION INTERFACE PACKETS

The TRMM spacecraft housekeeping data will be downlinked along with the science data packets for use in ground processing. Included in this data is ancillary data providing the necessary information to allow the ground based science data processing software to correlate the science data with UTC time, spacecraft position and attitude, and spacecraft operating mode/orientation (see Table 8.5-1).

Table 8.5–1
Ancillary Data

Data Type	Description
Attitude/Pointing	Observatory attitude errors, pitch and roll error signals denoting offsets from the Earth horizon bisector reference and yaw error signals determined by the yaw gyros. This data shall provide knowledge of spacecraft pointing with respect to a geodetic position.
Attitude Rate	The instantaneous inertial angular velocity of the TRMM Observatory along the body (roll, pitch, and yaw) axis.
Position	The position of the TRMM observatory shall be provided with respect to geocentric inertial coordinate system.
Velocity	The velocity of the TRMM observatory shall be provided with respect to geocentric inertial coordinate system.
Time	UT Correlation Factor
Direction Flag/ACS mode	Current Spacecraft Orientation/ACS mode

8.6 MIL-STD-1773 MODE CODES AND DIAGNOSTIC CAPABILITIES

The LIS instrument RTs shall implement the following mode codes per MIL-STD-1773:

a. 00010 : Transmit Status Word

b. 00100 : Transmitter Shutdown

c. 00101 : Override Transmitter Shutdown

d. 01000 : Reset Remote Terminal.

Of these, only item (d) will be sent by the FDS during normal flight operations

In addition, the LIS instrument RTs are required to implement a data "wrap around" function (see MIL-STD-1773 appendix notes 30.7 Data Wraparound (4.3.3.5.1.4)). The RTs shall use receive subaddress #30 to which up to 32 data words of any bit pattern can be received. A valid receive message to subaddress #30 followed by a valid transmit command to subaddress #30 with the same word count and without any intervening valid commands to the RT shall cause the RT to respond with each data word having the same pattern corresponding to the received data.

9. CONTAMINATION

9.1 GENERAL

The LIS instrument design shall provide for minimization of contamination to and from external sources before, during, and after launch, and for access for removal of pre-launch contamination. Remotely actuated deployable covers may be employed to protect critical surfaces. A contamination control plan shall be developed in compliance with the TRMM PAR (TRMM-303-006).

9.1.1 Instrument Venting

The LIS instrument vent locations and paths are identified in Figure 9.1–1. Venting paths will be reviewed by GSFC contamination control personnel to ensure that TRMM observatory sensors or other instruments contamination sensitive areas are not affected.

9.1.2 Covers and Purges

The use of protective covers and purges shall be as specified in the LIS instrument Contamination Control Plan. MSFC will furnish any protective covers required. Temporary protective covers shall be removed for flight and tests as described in the LIS instrument field handling procedures.

9.1.3 Storage and Operations

All units shall be configured so that they can be stored and operated in the following clean room conditions, for extended periods of time, without requirements for power or purge. During these periods the temperature shall be maintained at 15-30°C, 30-50% relative humidity and the cleanliness shall be a class 100,000 as a minimum.

9.2 PLUME IMPINGEMENT

The LIS instrument shall be designed to withstand the thruster effluent impingement shown in Table 9.1–1.

Table 9.1–1
Total Thruster Effluent Impingement

1/4/93

	Thruster Contamination Species (g/cm^2)					
Instrument	NH_3	N_2	H_2	N_2H_4	$C_6H_5NH_2$	H_2O
LIS	$3.1x10^{-4}$	$3.6x10^{-5}$	$7.6x10^{-4}$	$7.9x10^{-7}$	$2.1x10^{-7}$	$1.5x10^{-6}$

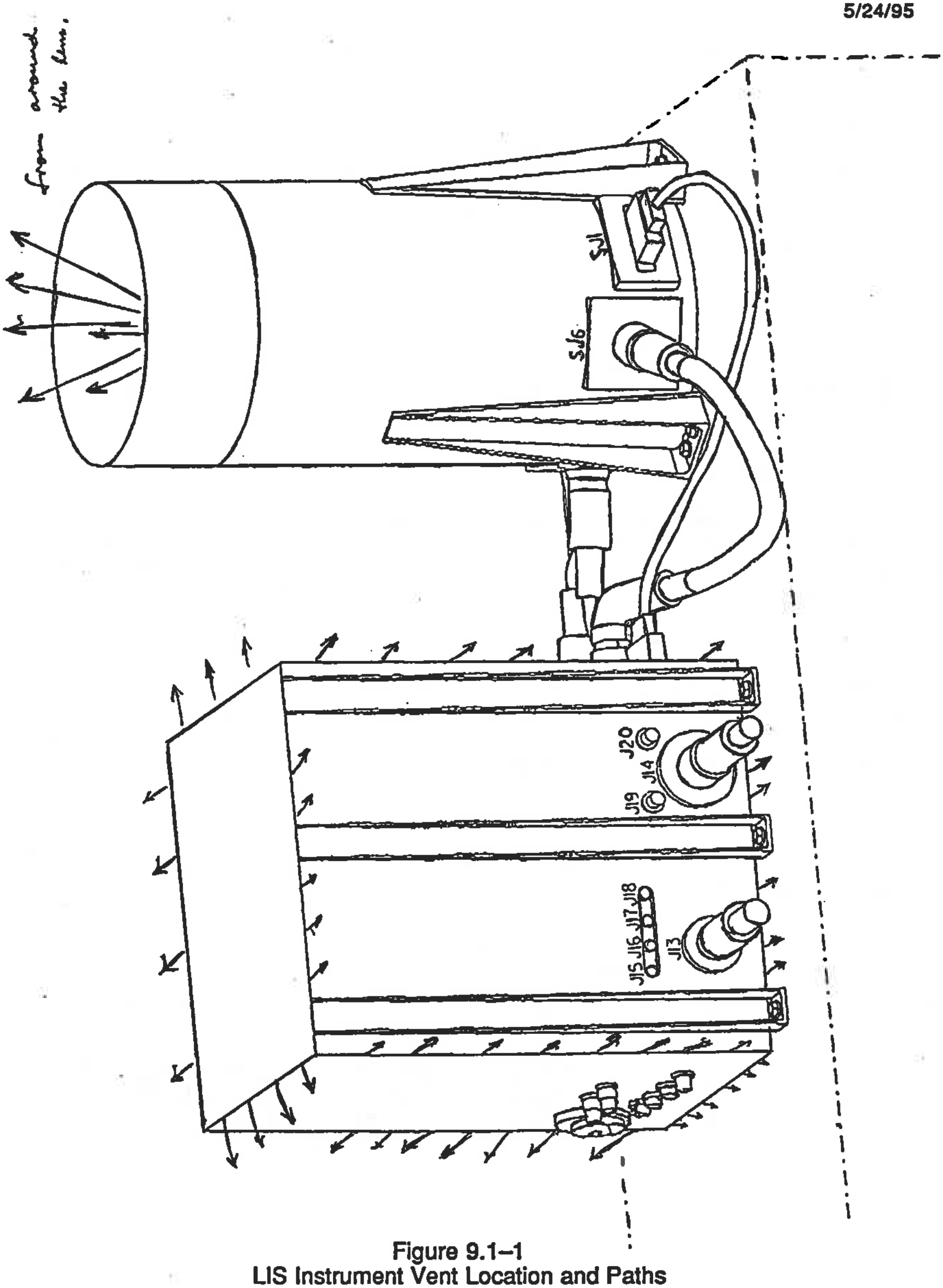


Figure 9.1–1
LIS Instrument Vent Location and Paths

9.3 OUTGASSING

There shall be no degradation of LIS instrument performance due to self contamination from outgassing materials, nor due to contamination from materials used on the spacecraft. Those non-metallic materials, which are used in constructionof the LIS instrument, shall not suffer a total weight loss of greater than 1.0 percent. Total volatile-condensable materials shall be less than 0.1 percent. Additional information is contained in test procedure ASTM E 595-77.

Spacecraft to instrument contamination and instrument cross-contamination will be controlled in accordance with the TRMM Contamination Control Plan, Document TRMM-732-016.

9.4 PARTS AND SUBASSEMBLIES BAKE-OUT

Thermal vacuum bake-out of MLI, wire harnesses, and other parts or subassemblies with high initial outgassing characteristics shall be performed before final assembly to limit self contamination and facilitate compliance with the instrument certification requirements of paragraph 9.5. The parameters (e.g., verification method, temperature, duration, pressure) of such bake-outs must be individualized depending on materials used, the fabrication environment, and the established contamination allowance. The bake-out parameters shall be documented or referenced in the instrument contamination control plan. It is recommended that all subassembly bake-outs be monitored with temperature-controlled quartz crystal microbalances (TQCMs).

9.5 INSTRUMENT CERTIFICATION REQUIREMENTS

In order to minimize cross contamination between the instruments and spacecraft sensitive surfaces, each instrument, regardless of its contamination sensitivity, must meet the following minimum cleanliness requirements.

The external surfaces of the LIS instrument shall be visibly clean highly sensitive per JSC-SN-C-0005 when inspected with a high intensity white light and black light from a distance of 15 to 30 cm (6 to 12 inches) upon delivery to GSFC. The surface cleanliness will be verified by GSFC personnel at delivery.

At delivery, the LIS instrument will also be subjected to a molecular level test known as a Solvent Wash. A small representative section of the instrument's exterior will be washed with a solvent and the residue will be collected. This test will be performed to ensure the instrument's exterior molecular level is less than 1.0 mg/ft^2. The Solvent Wash test will be performed by GSFC contamination analysis personnel under supervision of MSFC personnel.

During the last hot cycle of instrument-level thermal vacuum testing, the instrument must demonstrate that it does not outgas at a rate greater than or equal to $5.30 \times 10^{-8} g/cm^2/hr$ at the telescope vent and $1.70 \times 10^{-7} g/cm^2/hr$ at the electronics box for 5 consecutive hours when at the maximum instrument operating temperature. These cleanliness criteria will be verified using the deposition rates experienced by

Temperature-Controlled Quartz Crystal Microbalances (TQCMs) maintained at -20° C +/-2°C and positioned to observe the effluent flux of each individual source areas listed above. The deposition rate requirements that correspond to each of the required outgassing rates will be provided by GSFC once details regarding chamber geometry, bakeout environment and procedures, and TQCM locations and orientations have been provided to GSFC contamination engineers. TQCM positioning must be coordinated with the GSFC contamination engineer before initiation of any thermal-vacuum operation.

9.6 FABRICATION, ASSEMBLY, AND INTEGRATION REQUIREMENTS

To minimize particulate contamination during observatory fabrication, assembly and integration, assembled flight hardware shall be maintained in a clean environment equivalent to class 10,000. When the LIS instrument and/or its subsystems are not being worked on or tested they shall be properly protected from contamination.

The fabrication and integration of all critical subassemblies, mechanisms, and components shall be performed in accordance with the LIS Contamination Control Plan.

9.7 CLEANING REQUIREMENT

The LIS instrument support team will be responsible for cleaning the LIS instrument during observatory integration and testing.

10. INTEGRATION, TEST AND VERIFICATION REQUIREMENTS

10.1 TEST FLOW

Observatory-level functional testing is to be performed utilizing the TRMM Ground System. The testing and use of instrument ground support equipment (IGSE) is the responsibility of MSFC.

10.2 PRE-INTEGRATION CHECKS

Various checks shall be made to the LIS instrument components to ensure compatibility with the mechanical and electrical spacecraft interfaces.

10.3 INTERFACE COMPLIANCE TEST

The electrical interfaces shall be verified by placing breakout boxes (BOB) in series with the electrical interconnect harness. The break out boxes will be provided by GSFC.

10.4 INTERFACE VERIFICATION

LIS instrument verification requirements are summarized in Table 10.4–1.

Table 10.4–1
Instrument Verification Requirements

Requirement	Acceptable Test Type	Methodology
Structural Loads (strength qual.)	Static Loads, Sine Burst, or Sine Sweep	<u>Test and Analysis</u> or Option <u>Test</u>: See Acceptable Test Type The <u>protoflight test level</u> (qualification level) shall be <u>1.25 x limit load</u> and the acceptance test level shall be 1.00 x limit loads. <u>Analysis</u> The strength qualification must be accompanied by a stress analysis that predicts a positive margin at stresses equal to 1.4 times the limit load for all ultimate failure modes. <u>Optional Method</u> If appropriate development tests are performed and stringent quality control procedures invoked, strength qualification may be accomplished by analysis which shows positive margins on yield at 2.0 x limit loads and positive margins on ultimate at loads 2.6 x limit loads
Structural Reliability	See Structural Loads	Fracture Control Program, Proof Loads Test or a Combination of the two.

Table 10.4–1 (continued)
Instrument Verification Requirements

Requirement	Acceptable Test Type	Methodology
Structural Reliability	See Structural Loads	Test to be performed on all flight hardware to acceptance levels (1.00 x limit load). If the flight instrument meets its structural loads requirement by testing to protoflight levels, it will also fulfill the structural reliability requirement.
Random Vibration	Three axis Random Vibration	The test item shall be subjected to vibration along each of three mutually perpendicular axes for one minute. The protoflight level shall be the limit level +3dB.
Mechanical Shock		Actuation of all shock producing devices. (Pyrotechnic or pneumatic actuated to release beams/protective covers. Shock testing will be done at the S/C level.)
Modal Survey	Sine Sweep	A modal survey test is required if the subsystem resonances are not above 50 Hz. Frequency determination done by low level sine sweep.
Mass Properties	Weight, Center of Gravity, and Moments of Inertia	The mass properties of the instrument shall be verified by analysis and or measurement. The following parameter shall be measured: Weight, Center of Gravity and Moments of Inertia. The instrument will be weighed upon delivery to GSFC.

Table 10.4–1 (continued)
Instrument Verification Requirements

Requirement	Acceptable Test Type	Methodology
EMC/EMI	Conducted Emissions, Radiated Emissions, Conducted Susceptibility, and Radiated Susceptibility (MIL-STD-461C and 462)	The EMC tests are intended to verify that the instrument will operate properly if subjected to conducted or radiated emissions from other sources and that the instrument does not generate either conducted or radiated signals that could hinder the operation of other systems. The instrument shall be subjected to a conducted susceptibility using CS01 and CS02 (powerlines) and CS06 (powerline transients) of MIL-STD-462. The instrument shall be subjected to radiated susceptibility using RS03 of MIL-STD-462. The instrument shall be subjected to conducted emissions tests using CE01 and CE03 of MIL-STD-462. The instrument shall be subjected to radiated emissions using RE02 of MIL-STD-462.

Note: MAGNETICS TEST MAY HAVE TO BE PERFORMED

10.5 GROUND SUPPORT EQUIPMENT (GSE)

The GSE consists of both the electrical and the mechanical support equipment needed to test, operate, and handle the LIS instrument during integration and testing and throughout the launch operations.

10.5.1 Instrument Ground Support Equiment (ISGE)

The IGSE is, specifically, the electrical and data processing equipment required to operate the instrument and to test and verify its functional performance throughout the development, integration, test, and launch phases of the project. The IGSE shall be capable of issuing commands to the instrument and processing the science, engineering, and housekeeping telemetry from the instrument by direct connection to the instrument and, alternatively, via connection to the Ethernet interface of either the Spacecraft Ground Support Equipment (SGSE) or the GSFC provided Spacecraft Interface Simulator. The IGSE shall be capable of recording and analyzing all instrument data whether being received in real-time from the instrument or as play-back data from a history tape.

The IGSE shall be used to operate the instrument during performance verification and calibration testing at the instrument developer's facility. It shall be used at the GSFC for instrument functional testing at the time of delivery (prior to integration) and after integration to the TRMM spacecraft in support of the observatory electrical performance and environmental tests. The IGSE shall also be used at the launch site for electrical performance tests and pre-launch activities.

After the instrument is integrated onto the TRMM observatory, the IGSE shall be integrated into the observatory SGSE local area network which utilizes the TCP/IP protocol over Ethernet for the exchange of command and telemetry data. As part of the overall observatory integration and test system, the IGSE shall be used to monitor and control the instrument during all subsequent tests.

The IGSE interfaces are shown in Figure 10.5–1.

10.5.2 Electrical

MSFC shall provide electrical ground support equipment (EGSE) falling into two categories:

a. Electrical support

b. Stimulus.

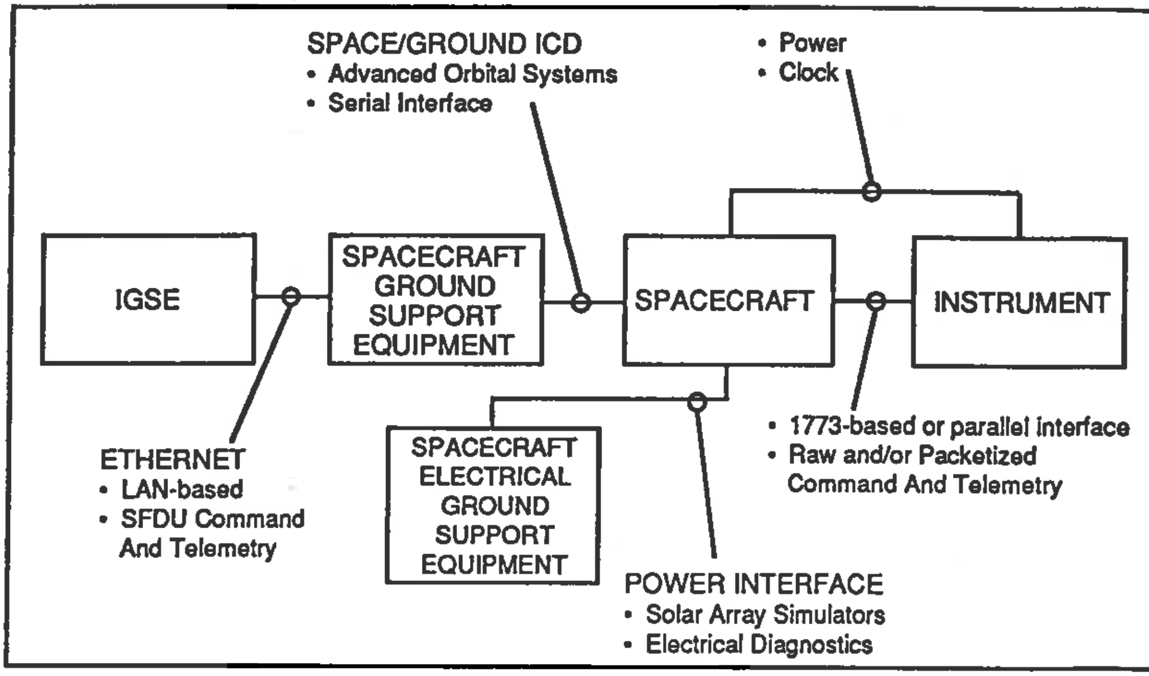
10.5.2.1 Electrical Support Equipment

The electrical support equipment contains the power supplies and simulated spacecraft signal sources. Instrument data monitoring capability is also provided by the electrical support equipment.

Table 10.4–1 (continued)
Instrument Verification Requirements

Requirement	Acceptable Test Type	Methodology
Thermal Vacuum/Thermal Balance		The instrument shall be subjected to thermal vacuum testing to ensure that the instrument can perform satisfactorily within the vacuum and thermal mission limits. The thermal balance test shall ensure the adequacy of the thermal design as embodied in the analytical model. A temperature margin of no less than 10°C above the predicted maximum operating conditions and 10°C below the minimum operating conditions shall be used in establishing test temperatures. The instrument shall be subjected to a minimum of eight thermal vacuum cycles before being integrated onto the spacecraft.

INSTRUMENT/OBSERVATORY INTEGRATION



INSTRUMENT & IGSE INTERFACE VERIFICATION

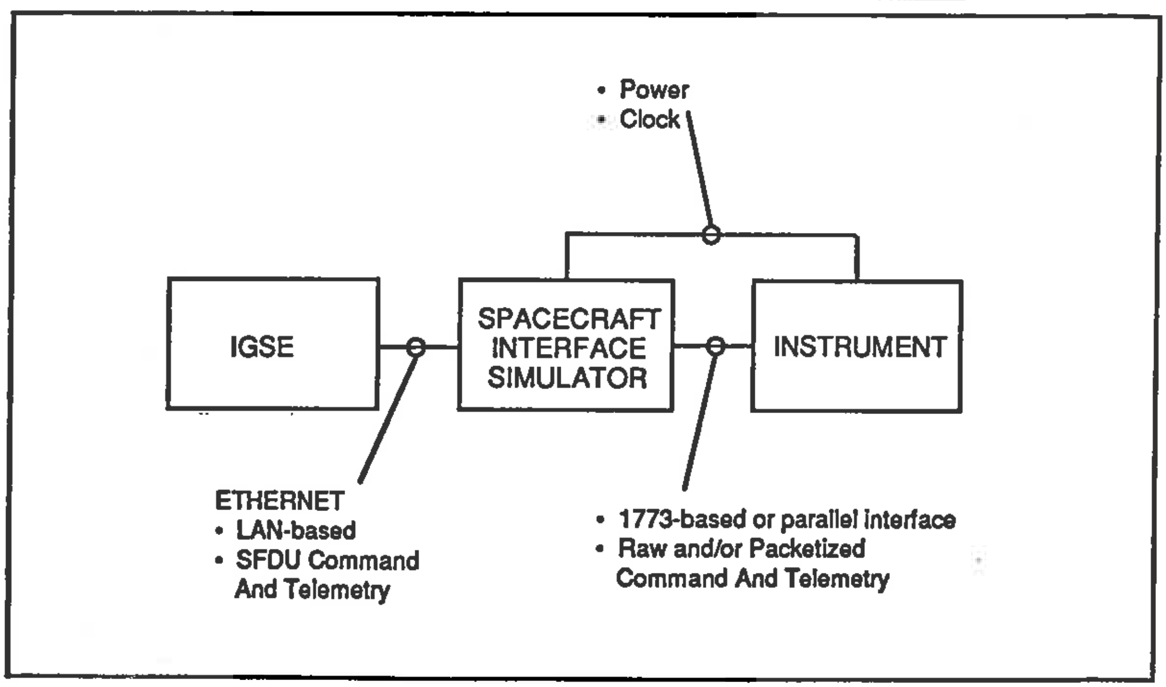


Figure10.5–1
GSE Interface Diagram

10.5.2.2 Stimulus Equipment

The stimulus equipment contains any additional equipment needed to stimulate or exercise the LIS instrument so that all of its modes of operation may be observed.

10.6 TEST INTERFACES

The test interfaces for the LIS instrument are J8 through J12 and J21. Figure 10.6–1 shows the test connector locations. For flight configuration, the LIS instrument shall provide non-radiating caps/covers for all test connectors.

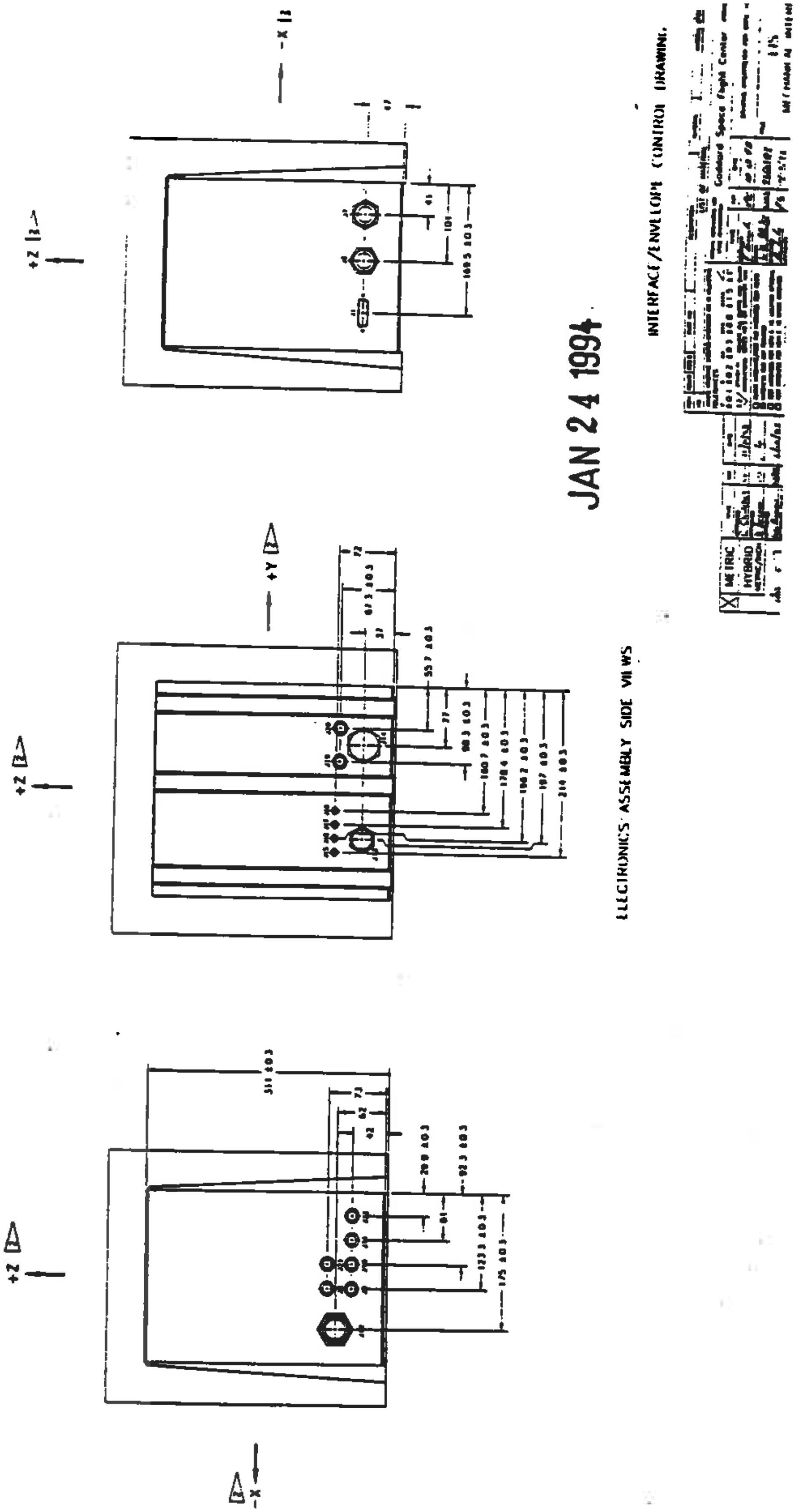


Figure 10.6–1
TRMM Spacecraft/LIS Instrument Test
Connector Location

11. SAFETY

The safety requirements for the LIS instrument shall be in accordance with the TRMM PAR (TRMM-303-006).

In addition, MSFC shall perform hazard analyses to identify potential hazard(s) which may originate from the instrument, IGSE, and related software. The analyses shall be performed at the component and instrument levels, and shall identify all hazards affecting personnel, launch vehicle, observatory, observatory GSE, and other payload instruments. The hazard analysis shall be included in the safety data package and updated as the hardware progresses through the various stages of design, fabrication, transportation, integration, and test.

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