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LANDSAT DATA CONTINUITY MISSION

LDCM Observatory Interface Requirements Document

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Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

CM FOREWORD

This document is a Landsat Data Continuity Mission (LDCM) Project Configuration Management (CM)-controlled document. Changes to this document require prior approval of the applicable Configuration Control Board (CCB) Chairperson or designee. Proposed changes shall be submitted to the LDCM CM Office (CMO), along with supportive material justifying the proposed change. Changes to this document will be made by complete revision.

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LDCM PROJECT
DOCUMENT CHANGE RECORD

REV LEVEL	DESCRIPTION OF CHANGE	DATE APPROVED
Rev. –	Baseline Release. Approved by CCR 427-000009.	01/04/07
Rev. A	Section 3.3.1.9.2.3: Clarify Translational Disturbance Environment Disclaimer. Section 3.3.1.9.2.4: Clarify Rotational Disturbance Environment Disclaimer. Approved by CCR 427-000014.	01/26/07
Rev. B	Updated per spacecraft studies, RF/Communication Study, comments from instrument vendors draft RFO comments from vendors and requirement clarifications. Approved by CCR 427-07-06-002. Added Appendix A with 4 Attachments. Approved by CCR 427-07-02-006	11/30/2007

TABLE OF CONTENTS

LIST OF FIGURES

Figure Page

LIST OF TABLES

1.0 SCOPE

1.1 IDENTIFICATION

This LDCM Observatory Interface Requirements Document (O-IRD) sets forth the general, common interface requirements imposed between the science instrument suite, (the Operational Land Imager (OLI), the Thermal InfraRed Sensor (TIRS) instrument, and the Total Solar Irradiance Sensor (TSIS) and the spacecraft for LDCM.

1.2 APPLICABILITY

Throughout this document reference will be made to “the OLI”, “the TIRS”, "the TSIS", “the (LDCM) spacecraft”, and “the instrument.” References to individual instruments, i.e. “the OLI” or “the TIRS” or "the TSIS" apply only to that instrument; reference to “the spacecraft” or “the LDCM spacecraft” applies only to the LDCM spacecraft; and reference to “the instrument” or “the instruments” apply equally to both the OLI, the TIRS, and the TSIS.

The spacecraft will be designed to accommodate the three instrument complement in accordance with this IRD. The design will be tailorable to permit specific accommodation options which include "OLI only," "OLI and TIRS," and "OLI and TSIS." The instrument complement will be finalized after spacecraft award.

1.3 TERMINOLOGY

Throughout this document the following definitions are used:

The term *spacecraft* is interchangeable with spacecraft bus or bus, and refers to all parts of the space segment that are not the instruments.

The term *Observatory* refers to the fully or partially integrated system, including the spacecraft and one or more instruments. This term is used mainly in reference to testing to differentiate between the spacecraft bus without instruments, and the integrated satellite with instruments.

The expression *instrument provider* refers to the organization / company delivering the instruments for integration on the spacecraft. The term is used interchangeably with the instrument contractor or sensor subcontractor with respect to LDCM. For the purposes of this document, the instrument provider is treated as a single entity, although in reality, the integrating team will probably include representatives from many organizations.

The expression *separately-mounted instrument components* refers to each part of an instrument which is separately mounted onto the spacecraft by the spacecraft contractor. Where an instrument is divided into multiple pieces, but is mounted onto the spacecraft via a single baseplate, that is not considered ‘separately-mounted’ instrument components in this document.

The term "(TBD)", which means "to be determined", applied to a missing requirement means that the instrument contractor should determine the missing requirement in coordination with the spacecraft contractor.

The term "(TBS)", which means "to be specified", means that the spacecraft contractor will supply the missing information in the course of the contract. These serve as a placeholder for future requirements. The instrument contractor is not liable for compliance with these "placeholder" requirements, as insufficient information is provided on which to base a design.

The term "(TBR)", which means "to be refined/reviewed", means that the requirement is subject to review for appropriateness by both contractor and the government, and subject to revision. The instrument contractor is liable for compliance with the requirement as if the "TBR" notation did not exist. The "TBR" merely provides an indication that the value is more likely to change in a future modification than requirements not accompanied by a "TBR".

1.4 DOCUMENT OVERVIEW

This O-IRD is controlled and maintained by the LDCM project office. The O-IRD is imposed on both the instrument contractor(s) and the spacecraft contractor, and will serve as a starting point for a detailed set of Interface Control Documents (ICD) and Mechanical Interface Drawings (MID) that will serve as the complete specification of the interfaces involved.

Attached as an appendix to this O-IRD and levied as an applicable document is a 16 day Design Reference Case (DRC-16). The DRC provides operational Observatory imaging and calibrations, and ground station availability expected for LDCM, consistent with on going Landsat operations.

The following Figure 1-1 shows the relationship between requirements documents for the LDCM mission.

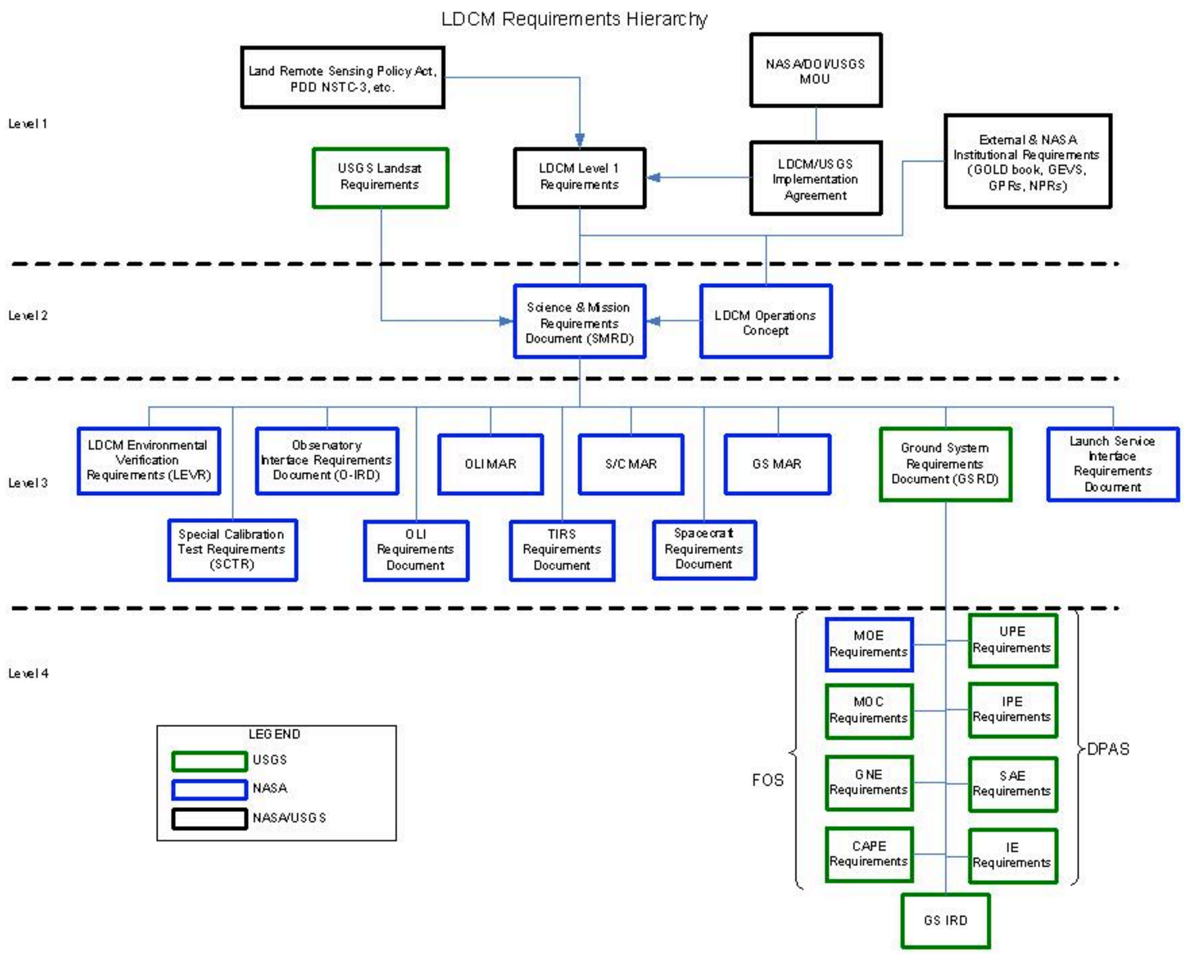


Figure 1-1. LDCM Requirements Tree

1.5 MECHANICAL INTERFACE DRAWINGS (MID) AND INTERFACE CONTROL DOCUMENTS (ICD)

MIDs and ICDs will be used to define the interfaces between the various contractor deliverables (e.g., instruments, spacecraft) during the LDCM implementation. After the instrument MIDs/ICDs have been provided by the instrument contractor or provider to the spacecraft contractor, the ICDs will be baselined in the spacecraft contractor CM system. The Government will maintain this O-IRD to track mission requirements.

1.6 RATIONALE

Throughout this document, there are paragraphs which are provided for information, rationale or clarification, but do not represent requirements. These are shown in italics. With such complimentary text, it is possible that the same or derived information may exist as a requirement, but any requirement is properly numbered.

2.0 APPLICABLE AND REFERENCE DOCUMENTS

2.1 APPLICABLE DOCUMENTS

The O-IRD is consistent with, and responsive to, the following applicable documents of the revision and release date shown. These documents establish detailed specifications, requirements, and interface information necessary for the performance of the contract. Unless otherwise stated in this document, all inconsistencies in the O-IRD will be resolved as defined in the Spacecraft Statement of Work.

The spacecraft contractor shall comply with the applicable documents listed below as they apply directly to the performance of the LDCM spacecraft contract.

Document Number	Document Title
450-SNUG	Space Network Users Guide, Revision 9
453-GNUG	Ground Network Users Guide, Revision 2
CCSDS 131.0-B-1	Recommendation for Space Data Systems Standards. TM Synchronization and Channel Coding. Blue Book. Issue 1.
CCSDS 133.0-B-1	Recommendation for Space Data Systems Standards. Space Packet Protocol. Blue Book. Issue 1.
CCSDS 231.0-B-1	Recommendation for Space Data Systems Standards. TC Synchronization and Channel Coding. Blue Book. Issue 1.
CCSDS 231.0-B-1, Cor. 1	Technical Corrigendum 1 to CCSDS 231.0-B-1
CCSDS 232.0-B-1	Recommendation for Space Data Systems Standards. TC Space Data Link Protocol. Blue Book. Issue 1.
CCSDS 301.0-B-3	Time Code Formats
CCSDS 401.0-B-17	Recommendation for Space Data Systems Standards. Radio Frequency and Modulation Systems
CCSDS 732.0-B-2	Recommendation for Space Data Systems Standards. AOS Space Data Link Protocol.
NPD 8010.2E	Use of the SI (Metric) System of Measurement in NASA Programs

2.2 LDCM DOCUMENTATION

The O-IRD is consistent with the following documents. Unless otherwise stated in this document, all inconsistencies in the O-IRD will be resolved as defined in the Spacecraft Statement of Work.

Document Number	Document Title
GSFC 427-02-02	LDCM Operations Concept Document
GSFC 427-02-06	LDCM Acronym List and Lexicon
GSFC 427-02-07	LDCM Worldwide Reference System-2 Memorandum
GSFC 427-03-04	LDCM Spacecraft Mission Assurance Requirements (MAR)
GSFC 427-06-03	LDCM Spacecraft Requirements Document (S-RD)
GSFC 427-03-05	LDCM Environmental Verification Requirements (LEVR)
GSFC 427-08-01	LDCM Launch Services Interface Requirements Document (LS-IRD)
GSFC 427-07-01	LDCM 16-Day Design Reference Case (DRC-16)
GSFC 427-06-01	LDCM Spacecraft Statement of Work

2.3 PRELIMINARY INSTRUMENT INTERFACE INFORMATION DOCUMENTS

The following reference documents provide Instrument Interface Information, including current best estimates (CBE's), design features, and details for instrument interfaces beyond what is addressed in this O-IRD. These documents will serve as a basis for the development of instrument to spacecraft ICD's.

Document Number	Document Title
2285215 Rev. C	OLI Instrument Interface Information OLI CDRL SE-11
GSFC 427-05-05	TIRS Instrument Interface Information
LASP 106924 Rev. -	TSIS Instrument Interface Information

3.0 OBSERVATORY INTERFACE REQUIREMENTS

3.1 GENERAL

The uncertainty, repeatability and variation values specified in this document are three (3) sigma unless specified otherwise. Ranges of values are considered not-to-exceed ranges. All other specification limits are not-to-exceed values unless specified otherwise.

3.2 RADIO FREQUENCY TELECOMMUNICATIONS SYSTEM

NASA/USGS has completed the system assessment for the RF wideband system in the X-band and Ka-Band frequencies. The ***Ka band option has been removed from consideration due to cost, and schedule risk.*** *Only the X-Band will be considered, either direct through High Gain Antennas (HGAs) or through Earth Coverage Antennas (ECAs) systems. It is the responsibility of the spacecraft contractor to ensure the proposed design meets the mission requirements; NASA/USGS will support either antenna implementation.*

3.2.1 General

The following Reference Table identifies applicable CCSDS standards.

CCSDS Reference Table				
	Command	Narrowband Telemetry	Wideband Telemetry	Document
CFDP	N/A	N/A	CCSDS 727.0-B-4	S-RD
Packets	CCSDS 133.0-B-1	CCSDS 133.0-B-1	CCSDS 133.0-B-1	O-IRD
Command (COP-1)	CCSDS 232.1-B-1	N/A	N/A	S-RD
Command Frames	CCSDS 232.0-B-1	N/A	N/A	O-IRD
Telemetry Frames	N/A	CCSDS 732.0-B-2	CCSDS 732.0-B-2	O-IRD
Randomization, Coding and Frame Sync.	CCSDS 231.0-B-1	CCSDS 131.0.B-1	CCSDS 131.0.B-1	O-IRD
Modulation	CCSDS 401.0-B-17	CCSDS 401.0-B-17	CCSDS 401.0-B-17	O-IRD

IRD-1887 The Spacecraft telecommunication interfaces shall use CCSDS Recommendations for Space Packet Protocol 133.0-B-1 for all command and telemetry packets.

IRD-1038 The Spacecraft telecommunication interfaces shall use CCSDS Recommendations for Advanced Orbiting Systems - Space Data Link Protocol 732.0-B-2 for all telemetry and science data streams.

IRD-1937 The Spacecraft telecommunication interfaces shall use CCSDS Recommendation, TC Space Data Link Protocol 232.0-B-1 for all command data streams.

3.2.2 Narrowband (S-Band)

IRD-1039 The Spacecraft shall communicate with the narrowband link through the NASA Space Network for duplexed command and telemetry in accordance with the 450-SNUG, S-Band Single Access (SSA) Telecommunications Services.

Rationale:

The services required from the TDRSS are its S-band communications. NASA SN will provide command and telemetry services for launch and early orbit, orbit maneuvers, and emergencies. There are no requirements for Doppler tracking, navigation, large data returns, etc. Low rate real time command and telemetry services will be limited to orbit maneuvers and declared operational emergencies. NASA SN offers near continuous coverage so the Spacecraft can be monitored or commanded at most times.

IRD-1041 The Spacecraft shall communicate via the narrowband link through the NASA Ground Network Support (GN) for command and telemetry in accordance with the 453-GNUG, Ground Network Users Guide.

Rationale:

NASA GN will provide back-up command and telemetry services to LDCM. NASA GN has the capability to provide high-margin, reliable communications when LDCM is in view of one of its worldwide locations. Real-time and stored/playback telemetry will be sent through the NASA GN.

IRD-1043 The Spacecraft shall communicate via the narrowband link to the LDCM Ground Network (LGN) for command and telemetry.

Rationale:

The LDCM LGN element of the Flight Operations Segment (FOS) provides for the day to day operational support to the LDCM mission. Command and telemetry is routed through these stations in real-time. These stations provide the primary and routine contact to the LDCM Spacecraft. Real-time and stored/playback telemetry will be sent through the LGN.

IRD-1056 The Spacecraft shall maintain 3 dB of link margin over 95% of the spherical coverage for narrowband command links with the LGN and GN at the end of Spacecraft design life.

Rationale:

3 dB margin for mission health & safety with LGN and GN. The 3 dB margin is in addition to all link-degrading effects; atmospheric attenuation and noise temperature contributions, and inter-symbol interference.

IRD-1938 The Spacecraft shall maintain 3 dB of link margin over 95% of the spherical coverage for narrowband telemetry links with the LGN and GN at data rates less than or equal to 32.768 kbps at the end of Spacecraft design life.

Rationale:

3 dB margin for mission health & safety with LGN and GN. The 3 dB margin is in addition to all link-degrading effects; atmospheric attenuation and noise temperature contributions, and inter-symbol interference.

IRD-1942 The Spacecraft shall maintain 3 dB of link margin in all Mission Mode nominal attitudes for the narrowband 1.048576 Mbps telemetry link with the LGN and GN at the end of Spacecraft design life.

IRD-1058 The Spacecraft shall maintain 0 dB of link margin over 90% of the spherical coverage for the narrowband 1.000 kbps command link with the SN at the end of Spacecraft design life.

Rationale:

Commanding is needed to maintain control of the Spacecraft during declared emergencies.

IRD-1940 The Spacecraft shall maintain 0 dB of link margin over 90% of the spherical coverage for the narrowband 2.048 kbps telemetry link with the SN at the end of Spacecraft design life.

Rationale:

Housekeeping telemetry is needed to maintain control of the Spacecraft during declared emergencies.

IRD-1943 The Spacecraft shall maintain 0 dB of link margin over at least 30% (TBR) of spherical coverage for the narrowband 16.384 kbps telemetry link with the SN at the end of spacecraft design life.

Rationale:

Provides needed TRDSS coverage for routine equatorial orbital maneuvers.

IRD-1060 The Spacecraft shall have a narrowband bit error rate (BER) at operational data rates, of less than or equal to 1E-6 after demodulation and application of all error correction code at the end of Spacecraft design life, for links to LGN stations.

Rationale:

The 1E-6 BER means there is a small chance of data being lost due to errors on the RF link.

IRD-1064 The Spacecraft shall have a narrowband bit error rate (BER) at operational data rates of less than or equal to 1E-6 after demodulation and application of all error correction code at the end of Spacecraft design life, for links to GN stations.

Rationale:

The 1E-6 BER means there is a small chance of data being lost due to errors on the RF link.

IRD-1065 The Spacecraft shall have a narrowband bit error rate (BER) at operational data rates of less than or equal to 1E-5 after demodulation and application of all error correction code at the end of Spacecraft design life, for links with the SN.

Rationale:

The BER for SN links is measured at the Space Network interface and includes only convolutional coding and no other error correction coding. 1E-5 is the lowest BER guaranteed by the SN at its interface.

IRD-1067 The Spacecraft shall support selectable randomization of the narrowband downlink in accordance with CCSDS-131.0-B-1.

Rationale:

Randomization ensures that high bit transition density is maintained regardless of data transmitted. High bit transition density aids reliable acquisition and tracking of the telemetry downlink.

IRD-1069 The Spacecraft shall support selectable randomization of the narrowband uplink in accordance with CCSDS-231.0-B-1

Rationale:

Randomization ensures that high bit transition density is maintained regardless of data transmitted. High bit transition density aids reliable tracking of the command link.

IRD-1073 The Spacecraft shall utilize error-correction coding compliant with CCSDS 131.0-B-1, Sections 3.1 and 4, applicable on narrowband downlinks.

Rationale:

Assuming the standard products for S-band; LGN already supports CCSDS standard. The CCSDS recommended coding is a commonly supported standard, with high coding gain.

IRD-1075 The Spacecraft shall process narrowband uplink coded for error correction following CCSDS 231.0-B-1.

Rationale:

The CCSDS recommended coding is a common standard.

IRD-1926 The Spacecraft shall utilize narrowband modulations consistent with CCSDS 401.0-B-17.

Rationale:

Modulations recommended in the CCSDS document are commonly supported standards.

3.2.3 Wideband (X-Band)

The Wideband Radio Frequency system for the LDCM Mission is required to transfer the Mission Data back to the LDCM Ground Stations as well as to the International Cooperators. The ground station specifications provided in this section represent the minimum capability provided by either an existing or planned system.

IRD-1085 The Spacecraft shall transmit realtime and playback wideband Mission Data to the LDCM Ground Network (LGN).

Rationale:

The Spacecraft must support Mission Data transmission to LGN in-view stations.

IRD-1262 The Spacecraft shall have wideband link availability to the LGN of 99% or greater at all elevation angles above the minimum elevation angle.

Rationale:

See Table 3-2 for elevation angles.

IRD-1087 The Spacecraft shall transmit real-time wideband Mission Data to up to three in-view International Cooperators (ICs) simultaneously.

Rationale:

The Spacecraft must support Mission Data transmission to in-view IC stations.

IRD-1089 The Spacecraft shall maintain 3dB of link margin in the nadir pointing attitude for the wideband transmission to the LGN station, in addition to all link-degrading effects (e.g. atmospheric attenuation and noise temperature contributions, and inter-symbol interference) at the end of Spacecraft design life.

Rationale:

3 dB margin for mission health & safety.

IRD-1091 The Spacecraft shall have a wideband transmission bit error rate (BER) of less than 1E-12 after demodulation and application of all error correction code at the end of Spacecraft design life.

Rationale:

A 1E-12 BER after coding corresponds to approximately one uncorrectable error per day and supports the high-reliability link required for efficient use of CFDP.

IRD-1093 The Spacecraft shall support selectable randomization of the wideband downlink in accordance with CCSDS-131.0-B-1.

Rationale:

Randomization ensures that high bit transition density is maintained regardless of data transmitted. High bit transition density aids reliable acquisition and tracking of the downlink.

IRD-1888 The Spacecraft shall utilize error-correcting coding compliant with CCSDS 131.0-B-1 on wideband downlinks.

Rationale:

The CCSDS recommended coding is a commonly supported standard by LGN and GN, with high coding gain.

IRD-1095 The Spacecraft shall utilize modulations on the wideband downlink consistent with CCSDS 401.0-B-17.

Rationale:

Modulations recommended in the CCSDS document are commonly supported standards.

3.3 SPACECRAFT TO GROUND INTERFACE REQUIREMENTS

This section is organized by external ground station interface with the spacecraft. The Spacecraft has four primary radio frequency (RF) interfaces as shown in Figure 3.1

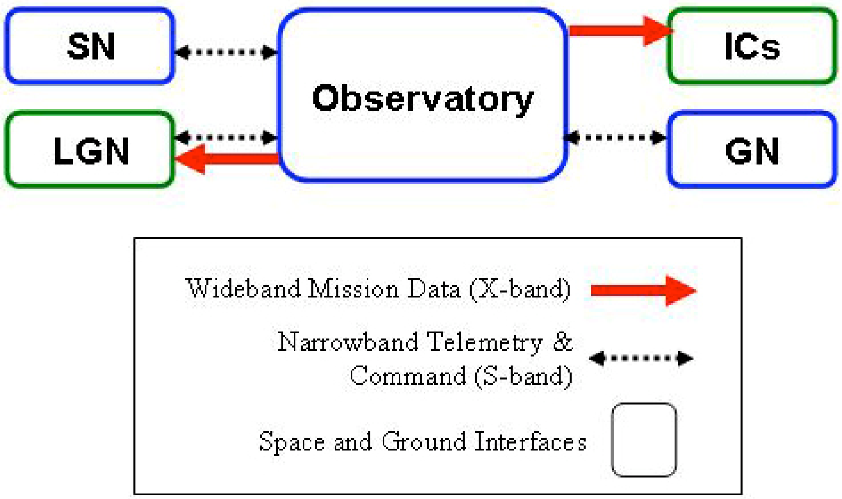


Figure 3-1. Spacecraft RF Interfaces

3.3.1 Narrowband (S-Band) to Ground Interface

3.3.1.1 NASA Space Network (SN)

IRD-1182 The Spacecraft shall receive commands at 1.000 kbps from the SN over the narrowband interface.

Rationale:

A declared emergency low rate is needed to command a tumbling spacecraft. The 1.000 kbps rate should be achievable with a fixed wide-beam antenna on the spacecraft and the Single Access TDRSS antenna over a large coverage area. Supported by the GN and LGN.

IRD-1185 The Spacecraft shall transmit real-time housekeeping telemetry at 2.048 kbps and 16.384 kbps to the SN over the narrowband interface.

Rationale:

A declared emergency low telemetry data rate is needed to meet the coverage requirements through TDRSS, and is supported by the GN and LGN. An orbit maneuver telemetry rate at 16.384 kbps is needed to meet the coverage requirements through TDRSS, and is supported by GN and LGN.

3.3.1.2 Spacecraft to LANDSAT Ground Network (LGN)

IRD-1116 The Spacecraft shall transmit real-time spacecraft housekeeping telemetry at 2.048 kbps, 16.384 kbps, and 32.768 kbps to the LGN over the narrowband interface. This requirement does not preclude any additional transmission rate(s).

Rationale:

The 32.768 kbps data rate provides sufficient throughput for the Observatory real-time telemetry, and supported by the GN. The 2.048 kbps data rate is the declared emergency telemetry rate used for TDRSS contacts and supported by the GN.

The specified rates are measured after Reed-Solomon coding and before rate 1/2 convolutional coding.

Additional rates supported from heritage design are acceptable but not required.

IRD-1120 The Spacecraft shall transmit combined real-time plus playback spacecraft housekeeping telemetry at a maximum of 1.048576 Mbps to the LGN over the narrowband interface.

Rationale:

This enables transmitting up to 3 orbits of back orbit data in a 10 minute pass, 5 passes to downlink 1 day of data. Rate supported by the GN.

IRD-1123 The Spacecraft shall receive real-time commands at 1.000 kbps and 32.000 kbps from the LGN, over the narrowband interface. This requirement does not preclude any additional transmission rate(s).

Rationale:

The 32.000 kbps data rate provides sufficient throughput for uploading the higher volume flight software patches or table loads, and is supported by the GN rates. The 1.000 kbps is the declared emergency command rate used with TDRSS, and also supported by the GN.

Command rates include BCH coding.

Additional command rates supported from a heritage design are acceptable but not required.

IRD-1125 The Spacecraft shall have link availability of 99% or greater at all elevation angles at or above the LGN station's minimum elevation angles for narrowband.

Rationale:

To ensure weather and atmospheric events will rarely interfere with the operators ability to use the command and telemetry links.

IRD-1126 The Spacecraft narrowband interface to the LDCM Ground Network shall be supported by the following LGN capabilities:

Table 3-1. LGN Narrowband RF Interfaces

Category	Narrowband LGN Capability
Antenna Location	LGN sites are in Sioux Falls, South Dakota and Fairbanks, Alaska.
S-Band Frequency Range	2200 MHz - 2290 MHz Receive 2025 MHz - 2108 MHz Transmit *GSFC Spectrum Management will assign a center frequency within this range*
Noise Specification for S-band	Minimum clear-sky S-band G/T at 5 degrees elevation is 20 dB/K.
Minimum Elevation Angle	5 degrees
Polarization	Left-hand Circularly Polarized (LHCP)
Demodulation - Downlink	BPSK, QPSK, SQPSK, OQPSK *Per CCSDS 401.0-B-17*
Modulation - Uplink	BPSK
Availability - Ground Station	Each LGN station has an availability of 97%. *Note: This is not link availability due to atmospheric effects.*
Equivalent Isotropic Radiated Power (EIRP)	54 dBW
Narrowband Uplink Sweep Range	± 160 KHz about the center frequency
Narrowband Uplink Sweep Rate	5 - 35 KHz/second

3.3.1.3 NASA Ground Network (GN)

IRD-1198 The Spacecraft shall interface with the NASA Ground Network (GN) for S-band forward and return services in compliance with the NASA Ground Network Users Guide (GNUG).

IRD-1210 The Spacecraft shall interface with the following NASA Ground Network ground stations:

- Svalbard, Norway - SGS
- Wallops, Virginia - WGS
- McMurdo, Antarctica - MGS
- Poker Flat, Alaska - AGS

Rationale:

Back-up GN stations.

IRD-1215 The Spacecraft shall transmit real-time spacecraft housekeeping telemetry data at 2.048 kbps, 16.384 kbps, and 32.384 kbps to the GN over the narrowband interface.

Rationale:

The 32.768 kbps data rate provides sufficient throughput for Observatory real-time telemetry, and also supported by the LGN. The 2.048 kbps data rate is the declared emergency telemetry rate used for TDRSS contacts, and supported by the LGN. The 16.384 kbps data rate is the orbit maneuver telemetry rate used for TDRSS contacts and supported by the GN.

The specified rates are measured after Reed-Solomon coding and before rate 1/2 convolutional coding.

Additional rates supported from heritage design are acceptable but not required.

IRD-1214 The Spacecraft shall transmit combined real-time and playback spacecraft telemetry at 1.048576 Mbps to the GN over the narrowband interface.

Rationale:

This enables transmitting up to 3 orbits of back orbit data in a 10 minute pass, 5 passes to downlink 1 day of data and supported by the LGN.

IRD-1213 The Spacecraft shall receive narrowband commands at 1.000 kbps, 32.000 kbps from the GN over the narrowband interface.

Rationale:

The 32.000 kbps data rate provides sufficient throughput for uploading higher volume flight software patches or table loads, and is supported by the LGN rates. The 1.000 kbps is the declared emergency command rate used with TDRSS, supported by the LGN.

IRD-1216 The Spacecraft shall have link availability of 99% or greater at all elevation angles at or above the GN station's minimum elevation angle for narrowband.

Rationale:

Links should be designed so that weather and interference will cause link degradation no more than 1% of the time. The Spacecraft will be able to use the NASA GN as a back-up for the S-band LGN capabilities.

3.3.2 Wideband (X-Band) to Ground Interface

Wideband transmission of Mission Data from the spacecraft to a ground station is provided by using a X-Band wideband system. The Mission Data may be either real-time data or previously recorded data (playback). The space to ground transmission combinations are:

a. The transmission of 1 realtime data stream of Mission Data to LGN.
b. The transmission of 1 realtime data stream and 1 playback data stream of Mission Data to LGN.
c. The transmission of 1 realtime data stream of Mission Data to at least 3 International Cooperators.
d. The transmission of 1 realtime data stream of Mission Data to LGN and at least 1 IC, and 1 playback data stream of Mission Data to LGN.
e. The transmission of 2 playback data streams of Mission Data to LGN.

Note: Data Stream is defined as a unique source of Mission Data either in real-time or as playback

IRD-1220 The Spacecraft shall provide wideband Mission Data transmissions to in-view International Cooperator (IC) and/or LGN ground stations in accordance with Tables 3-2, and 3-3.

3.3.2.1 Landsat Ground Network (LGN)

IRD-1102 The Spacecraft wideband interface to the LDCM Ground Network shall be supported by the following LGN capabilities in Table 3-2, LGN Wideband RF Interfaces:

Table 3-2. LGN Wideband RF Interfaces

Category	Wideband LGN Capability
Wideband Carriers	Two X-band carriers with polarization diversity are supported. *Note: 2 independent data streams.*
Antenna Location	LGN sites will be in Sioux Falls, South Dakota and Fairbanks, Alaska.
Wideband Frequency Range	8025 MHz to 8400 MHz *Up to 375 MHz of bandwidth for NTIA application. The center frequency(s) will be coordinated with GSFC Spectrum Management*
Noise Specification	Minimum clear-sky X-band G/T at 5 degrees elevation is 31 dB/K.

Category	Wideband LGN Capability
Minimum elevation angle	5 degrees
Polarization	Dual Polarization Left-hand Circularly Polarized (LHCP) and Right-hand circularly Polarized (RHCP)
Demodulation	QPSK, SQPSK, OQPSK, AQPSK, FOQPSK Per CCSDS 401.0-B-17
De-randomization	CCSDS-131.0-B-1 TM Synchronization/ Channel Coding, Blue Book Issue 1, September 2003 is supported
Availability - Ground Station	Each LGN station has an availability of 97%. *Note: This is not link availability due to atmospheric effects.*
Axial Ratio	1.5dB *Note: Includes feed, radome. Does not include weather.*

IRD-1641 The Spacecraft shall send combined real-time and playback spacecraft housekeeping telemetry to the LGN over the wideband interface.

3.3.2.2 International Cooperators (ICs)

IRD-1264 The Spacecraft wideband interface to IC ground stations shall be supported by the following IC capabilities in Table 3-3, IC Wideband RF Interfaces:

Table 3-3. IC Wideband RF Interfaces

Category	IC Wideband Capability
Wideband carriers	Single X-band carrier with RHC polarization is supported.
Wideband Frequency Range	8025 MHz to 8400 MHz *Up to 375 MHz of bandwidth for NTIA application. The center frequency(s) will be coordinated with GSFC Spectrum Management.*
Noise specification for X-band	Minimum clear-sky X-band G/T at 5 degrees elevation: 31 dB/K (TBR)
Minimum elevation angle	5 degrees
Polarizations	Right-hand circularly Polarized (RHCP)

Category	IC Wideband Capability
Demodulation	QPSK, SQPSK, OQPSK, AQPSK, FOQPSK Per CCSDS 401.0-B-17
De-randomization	CCSDS-131.0-B-1 TM Synchronization/ Channel Coding, Blue Book Issue 1, September 2003 is supported.

3.4 SPACECRAFT TO INSTRUMENT INTERFACE REQUIREMENTS

3.4.1 Mechanical Interface Requirements

IRD-127 All mechanical requirements specified shall be met at the mechanical interface; that is, at the surface(s) of the spacecraft where the instrument is in contact with the spacecraft, unless otherwise specifically indicated.

3.4.1.1 Dimensions

IRD-129 All interface documents and drawings shall use metric units per NPD 8010.2E, Use of the SI (Metric) System of Measurement in NASA Programs. An exception is allowed for interface documents in native imperial units.

IRD-938 The metric units shall be displayed with the imperial units.

IRD-130 Dimensioning shall be in the as-designed units, and identified when other than SI.

Rationale:

Existing engineering tools may be in heritage units.

IRD-132 The design of each instrument shall meet the dimensional envelope constraints defined in the ICD under a combination of static, dynamic, and thermal conditions encountered during factory assembly, system test, transportation and handling, launch, deployment, and on-orbit operations.

3.4.1.2 Reference Frames

3.4.1.2.1 Observatory Reference Frame

Reference Ellipsoid: The WGS 84 reference ellipsoid as defined by NIMA TR8350.2.

Geocentric Nadir: Defined at any point in the orbit as the direction toward the center of mass of the Earth.

<u>Inertial Velocity</u>: *The velocity relative to the Earth Centered Inertial (ECI J2000.0) reference frame.*

IRD-138 The LDCM Orbital Reference Frame shall be a right-handed, orthogonal, XYZ coordinate system defined such that the origin is at the spacecraft center of mass (CM), the +Z axis points toward Geocentric Nadir, the +X axis is coplanar with both the +Z axis and the spacecraft inertial velocity vector (and is in the general direction of the spacecraft inertial velocity vector), and the +Y axis completes the right-handed, orthogonal coordinate system as shown in Figure 3-2.

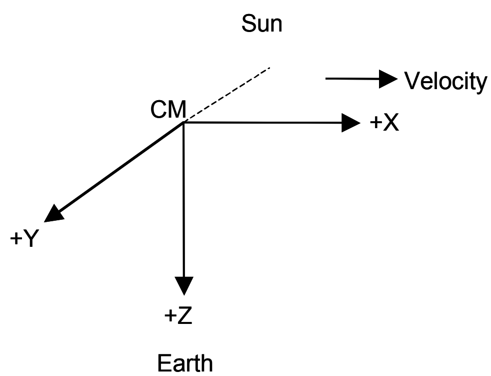


Figure 3-2. Orbital Reference Frame

3.4.1.2.2 Spacecraft Body Frame

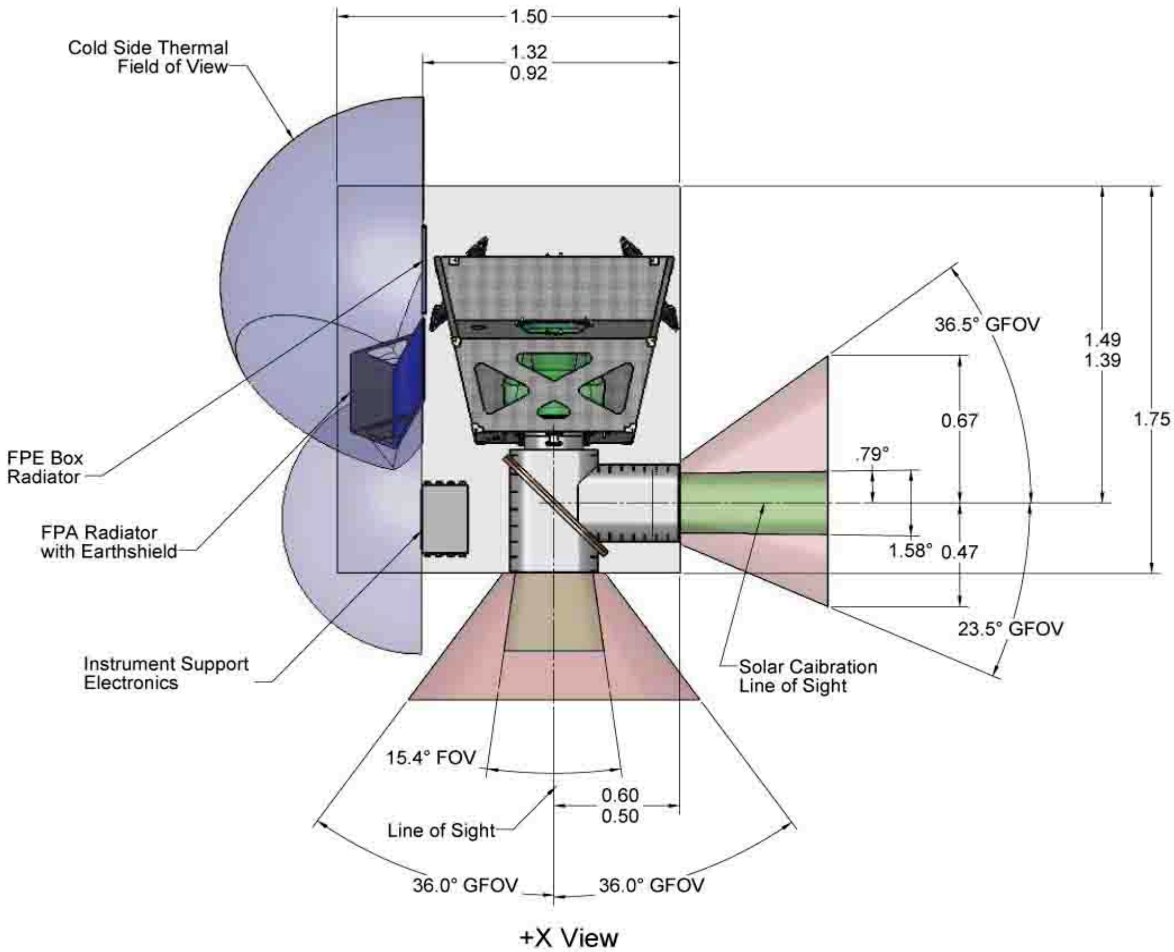
IRD-142 The LDCM Spacecraft Body Frame shall be a right-hand, orthogonal, body-fixed XYZ coordinate system with the +Z direction pointing to nadir.

IRD-143 The Instrument(s) Body Reference Frame shall be described in each Instrument's MID by the instrument contractor or provider.

3.4.1.3 Instrument Fields of View

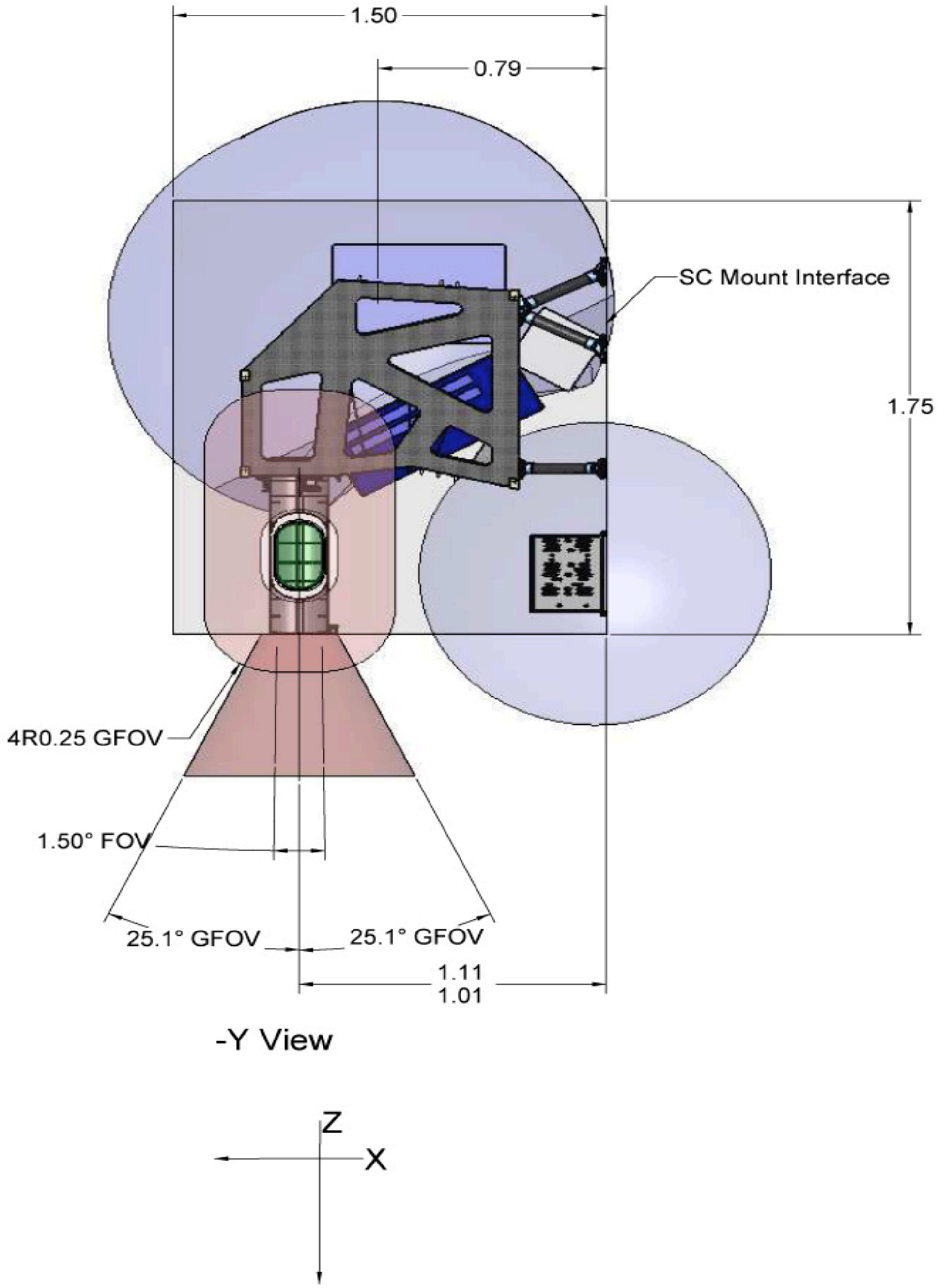
3.4.1.3.1 OLI Fields of View

OLI FOVs are shown in Figures 3-3, 3-4, and 3-5. The glint keepout fields have been chosen such that any non-diffuse source on the Observatory will not illuminate past the halfway point on the entrance baffle for the nadir imaging path or the edge of the diffuser for the solar calibration path. Specific FOV incursions into these keepout zones can be negotiated subject to a detailed assessment of the impacts on OLI's stray light performance.



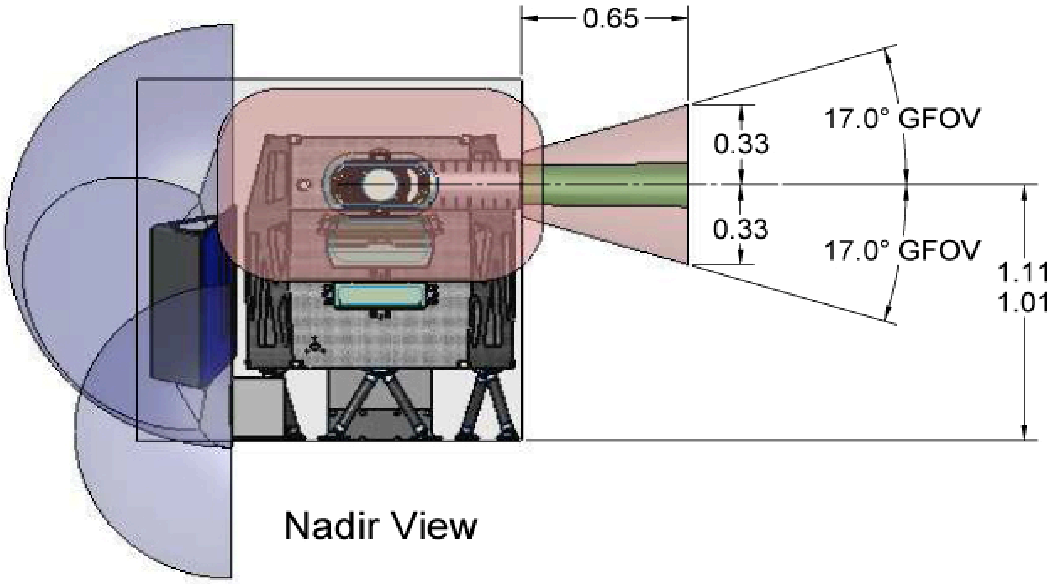
Note: Dimensional units in meters

Figure 3-3. OLI View (Looking in the -X Direction)



Note: Dimensional units in meters

Figure 3-4. OLI View (Looking in the -Y Direction)



Note: Dimensional units in meters

Figure 3-5. OLI Nadir View (Looking in the -Z Direction)

IRD-147 The LDCM spacecraft shall provide an unobstructed minimum glint free nadir field of view for OLI instrument that provides 36.0° x 25.1° half cone, as shown in Figures 3-3 and 3-4.

Rationale:

OLI science FOV = 15.4° x 1.50°

IRD-148 The boresight of the OLI unobstructed field of view shall be parallel to the nadir (+Z) axis.

IRD-150 The LDCM spacecraft shall provide an unobstructed minimum solar calibration glint free field of view for the OLI instrument, as shown in Figures 3-3, 3-5.

IRD-151 The OLI glint free solar calibration field of view for the indicated solar elevation range shall be 17° x (23.5°, 36.5°) in azimuth from the velocity vector as shown in Figures 3-3, 3-5.

Rationale:

OLI solar calibration science FOV = 1.58° full cone

3.4.1.3.2 TIRS Fields of View

IRD-154 The LDCM spacecraft shall provide an unobstructed minimum glint free nadir field of view for TIRS instrument that provides a 45° (TBR) full cone.

Rationale:

TIRS science FOV = 15° full cone.

IRD-155 The boresight of the TIRS unobstructed field of view shall be parallel to the nadir (+Z) axis.

3.4.1.3.3 TSIS Fields of View

3.4.1.3.3.1 TSIS Deployed Configuration

IRD-1637 The TSIS deployment axis range of motion shall be as shown in Figures 3-6.

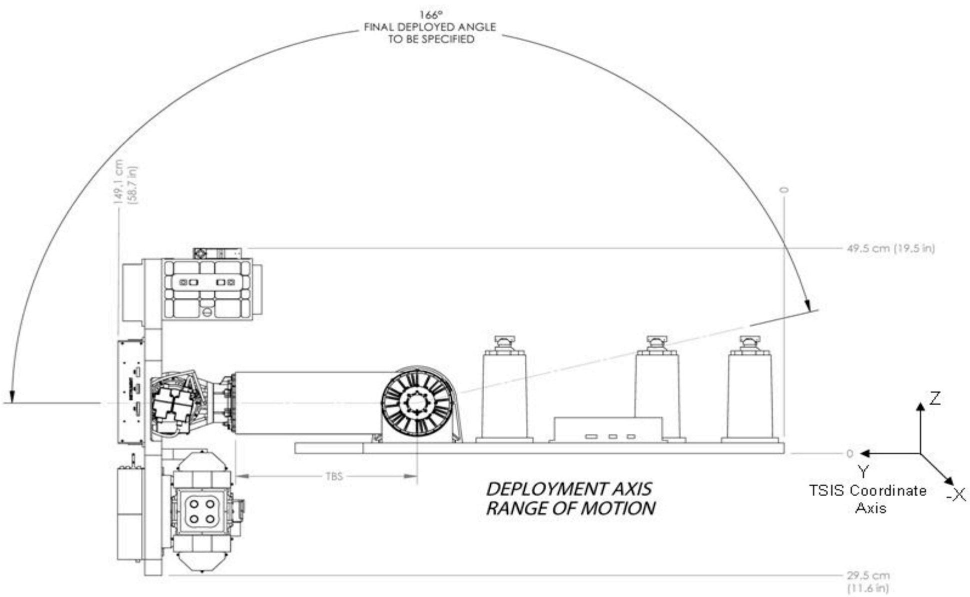


Figure 3-6. TSIS Deployment Range of Motion

IRD-1750 The TSIS azimuth range of motion shall be 355° after deployment, as shown in Figure 3-7.

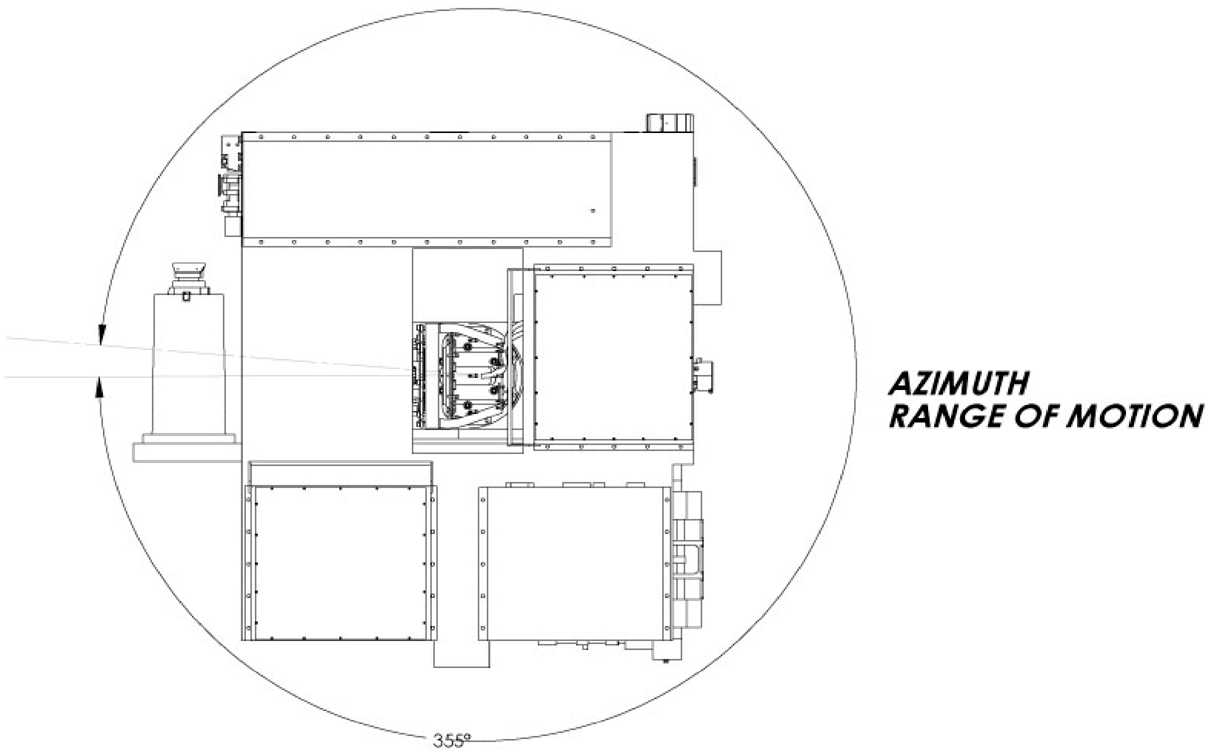


Figure 3-7. TSIS Azimuth Range of Motion after Deployment

IRD-1751 The TSIS elevation range of motion shall be 290° after deployment, as shown in Figure 3-8.

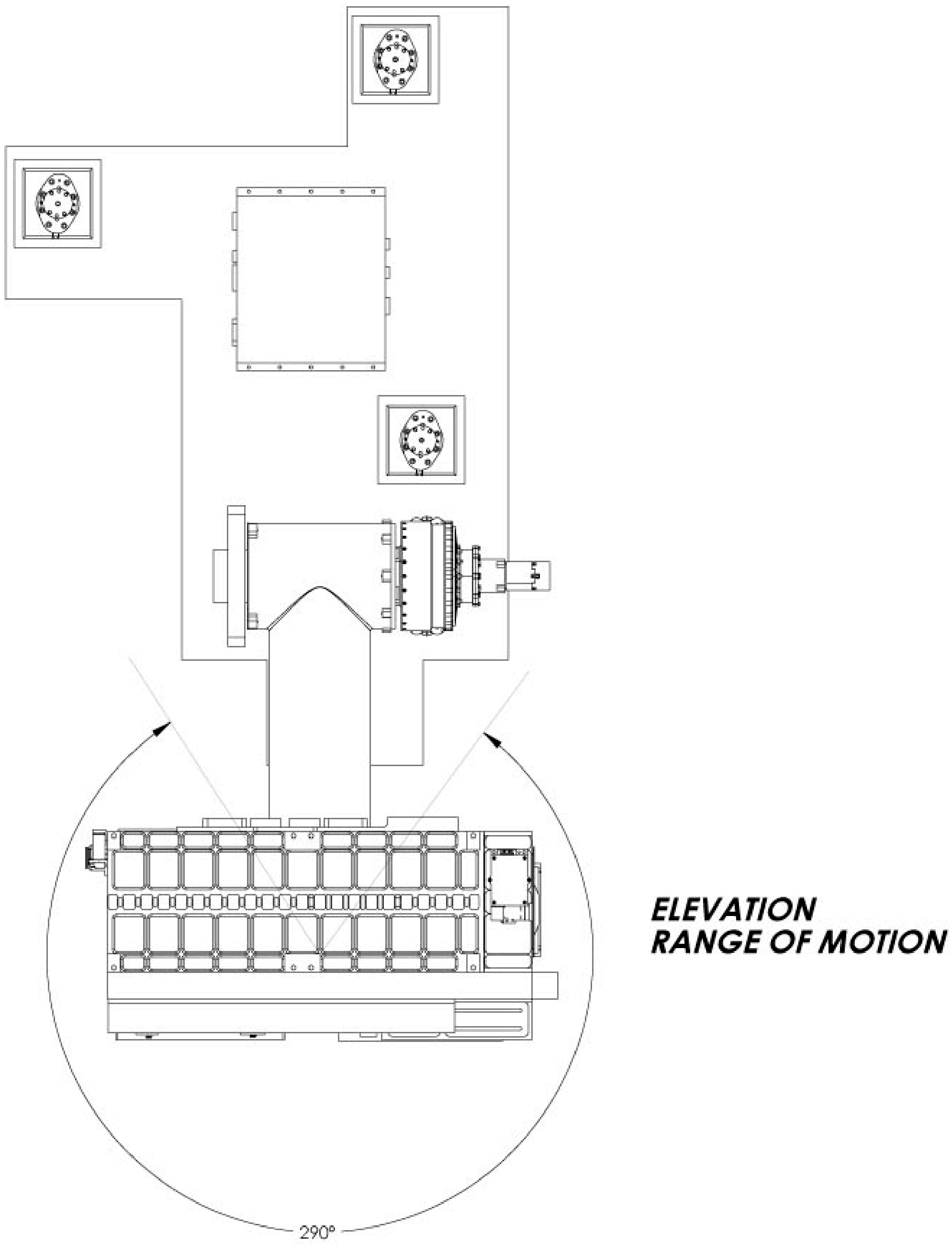


Figure 3-8. TSIS Elevation Range of Motion after Deployment

IRD-1316 The LDCM spacecraft shall provide an unobstructed minimum glint free field of view for TSIS that provides 4 degrees full cone for the SIM instrument.

Rationale:

SIM science FOV = 2.5° x 1.5°

IRD-1315 The LDCM spacecraft shall provide an unobstructed minimum glint free field of view for TSIS that provides a 40 degree full cone for the TIM instrument.

Rationale:

TIM science FOV = 6° full cone

3.4.1.4 Mass Properties

3.4.1.4.1 Mass Allocation

The defined not-to-exceed mass includes the basic instrument structure, instrument-unique mounts, instrument-unique mounting hardware, mounting feet, thermal blankets, connectors (instrument-side only), and intra-instrument harness (with connectors), as well as any other items that constitute any part of a deliverable instrument.

Instrument mass allocations (or "not to exceed") include margins that are in accordance with GSFC-STD-1000. The allocation includes the 30% above the current best estimate for each instrument. Additional margins (per Gold Rules) by the Spacecraft contractor are not required for instruments.

3.4.1.4.1.1 OLI Mass Allocation

IRD-165 The total mass of the OLI and all associated hardware, intra-instrument harnessing, and any attached external harnessing extending to the spacecraft connector interface shall not exceed 375 kg.

Rationale:

Assumes a 1.3 meter harness length between the FPE and ISE.

IRD-166 The mass of the OLI shall be measured to an accuracy of ± 0.2% at delivery to the spacecraft.

3.4.1.4.1.2 TIRS Mass Allocation

IRD-168 The total mass of the TIRS instrument including all associated electronic subsystems, intra-instrument harnessing, and external harnessing extending to the spacecraft connector interface shall not exceed 200 kg. (TBR).

Rationale:

A maximum length of 2 meters of wire harnessing is assumed.

IRD-169 The mass of the TIRS shall be measured to an accuracy of ± 0.2% at delivery to the spacecraft.

3.4.1.4.1.3 TSIS Mass Allocation

IRD-1323 The total mass of the TSIS and all associated hardware, intra-instrument harnessing, and external harnessing extending to the spacecraft connector interface shall not exceed 150 kg.

Rationale:

Spacecraft wire harness leads up to a bracket on TSIS instrument.

IRD-1436 The mass of the TSIS shall be measured to an accuracy of ± 0.2% at delivery to the spacecraft.

3.4.1.4.2 Center of Mass

3.4.1.4.2.1 Center of Mass Location

IRD-172 The typical launch and on-orbit center of mass of each separately mounted instrument component shall be documented in each instrument MID, referenced to the instrument coordinate axes.

IRD-173 The actual stowed (launch) and deployed (on-orbit) centers of mass of each separately-mounted instrument component shall be measured by the instrument contractor, reported to ± 6 mm (not-to-exceed), referenced to the instrument coordinate axes and documented in the data package for that serial number instrument.

Rationale:

In select cases, measurement of X and Y, and prediction of Z through analysis may be acceptable.

IRD-174 The instrument coordinate axes shall be defined to be in the same orientation as the spacecraft axes in each instrument ICD, but not necessarily the same origin.

Rationale:

Coordinates axis for TSIS are notionally defined in the Instrument Interface Information, and will be changed to meet Observatory coordinates when the mounting location on the spacecraft is identified.

3.4.1.4.3 Moments and Products of Inertia

IRD-176 The moments and products of inertia shall be measured or calculated for each separately-mounted instrument component, using coordinates based on the spacecraft axes but passing through the instrument component center of mass.

IRD-177 Moments and products of inertia shall be provided to the spacecraft contractor for documentation in the ICD.

3.4.1.4.3.1 Moments and Products of Inertia Accuracy

IRD-179 Moments and products of inertia values shall be accurate to within ± 5% for calculated values, and the lesser of 1.5% or 300 kg-cm_ for measured values.

Rationale:

Typically, products of inertia measurements to +/-1.5% are routine.

3.4.1.4.3.2 Moments and Products of Inertia Variation Documentation

IRD-181 If the instrument contains movable masses, expendable masses, or deployables, the typical respective moments and products of inertia variations during the deployment, specified at least at the beginning, middle, and end of the deployment, shall be provided to the spacecraft contractor for documentation in the ICD.

IRD-182 If an instrument contains movable masses or deployable items, the respective moments and products of inertia variations shall be measured or calculated and documented in the ICD.

3.4.1.5 Volume Allocation

IRD-191 The defined not-to-exceed instrument envelope shall include the basic instrument structure, instrument-unique mounts, instrument-unique mounting hardware, mounting feet, thermal blankets (including billowing during launch and ascent), connectors (instrument-side only), and intra-instrument harness (with connectors), as well as any other items that constitute any part of a deliverable instrument.

Rationale:

The intent of this requirement is that everything provided as part of a deliverable instrument, including the items identified above, be allocated against the instrument size and weight allocations, and that everything provided by the spacecraft contractor be held against the spacecraft allocation.

3.4.1.5.1 OLI Volume Allocation

IRD-185 OLI shall fit within an envelope of 1.5m (X) by 1.5m (Y) by 1.75m (Z).

3.4.1.5.2 TIRS Volume Allocation

IRD-1329 TIRS shall fit within an envelope of 0.8m (X) by 1.0m (Y) by 1.3m (Z) (TBR).

3.4.1.5.3 TSIS Volume Allocation

IRD-1330 TSIS shall fit within an envelope of 1.1m (X) by 1.5m (Y) by 0.5m (Z) in stowed configuration.

3.4.1.6 Stowed and Critical Clearances

IRD-189 The instruments shall fit within the static envelope of launch vehicle's fairing, while meeting the launch vehicle frequency requirements.

IRD-193 The spacecraft shall accommodate the instruments so as to maintain adequate clearance between the instrument and surrounding structures, in order to provide access to instrument mounting hardware, access to instrument connectors, and space for instrument interfacing harness service loops.

3.4.1.7 Documentation in MID

IRD-195 The instrument envelope shall be documented in each instrument MID by the instrument contractor or provider.

Rationale:

Documentation is to be in the form of engineering drawings with a set of "not to exceed" dimensions for the launch, deployed on-orbit, and installation envelopes. The instrument installation envelope is defined as the volume of the instrument including the attached lifting sling.

IRD-197 All instrument fields of view, including, where applicable, optical, glint, electronics radiator, optical cube fields of view, and solar diffuser fields of view, shall be documented in each instrument MID by the instrument contractor or provider.

IRD-198 Information on field-of-view-related issues such as clearances, multi-path tolerances, indirect effects such as glint and allowable secondary radiation, and percent interference allowed shall be documented in each instrument MID by the instrument contractor or provider.

3.4.1.8 Mounting Provisions

3.4.1.8.1 Instrument Deck

IRD-201 The spacecraft shall provide an instrument deck as the mounting surface for the OLI and TIRS instruments, and AOCS sensor components.

IRD-202 The instrument deck shall be constructed of a low coefficient of thermal expansion (CTE) material (such as a composite material) to support the OLI and TIRS instruments.

3.4.1.8.2 OLI Mounting Provisions

IRD-1620 The instrument reference frame mounting interface of the OLI optical bench shall be the -X face of the instrument as indicated in Figure 3-9.

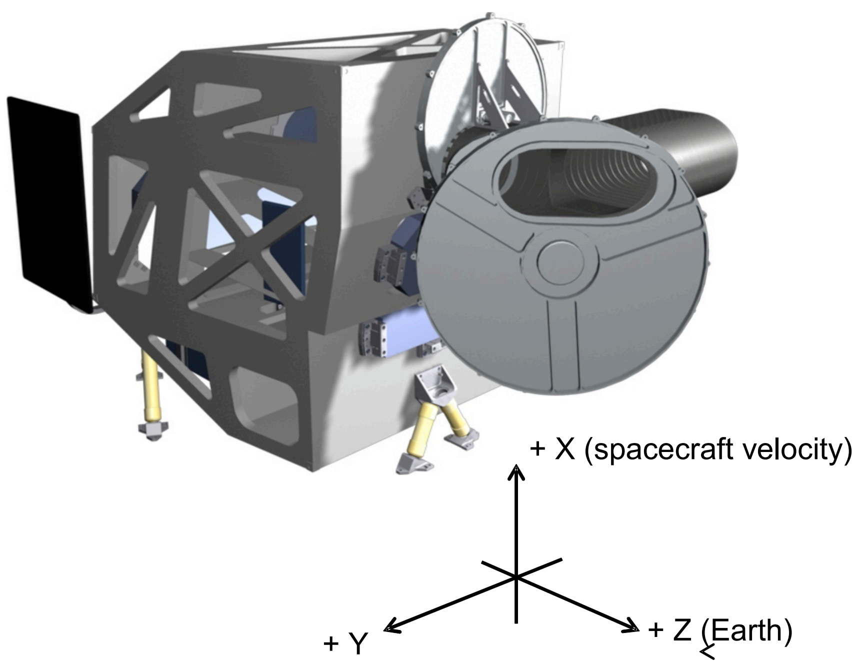


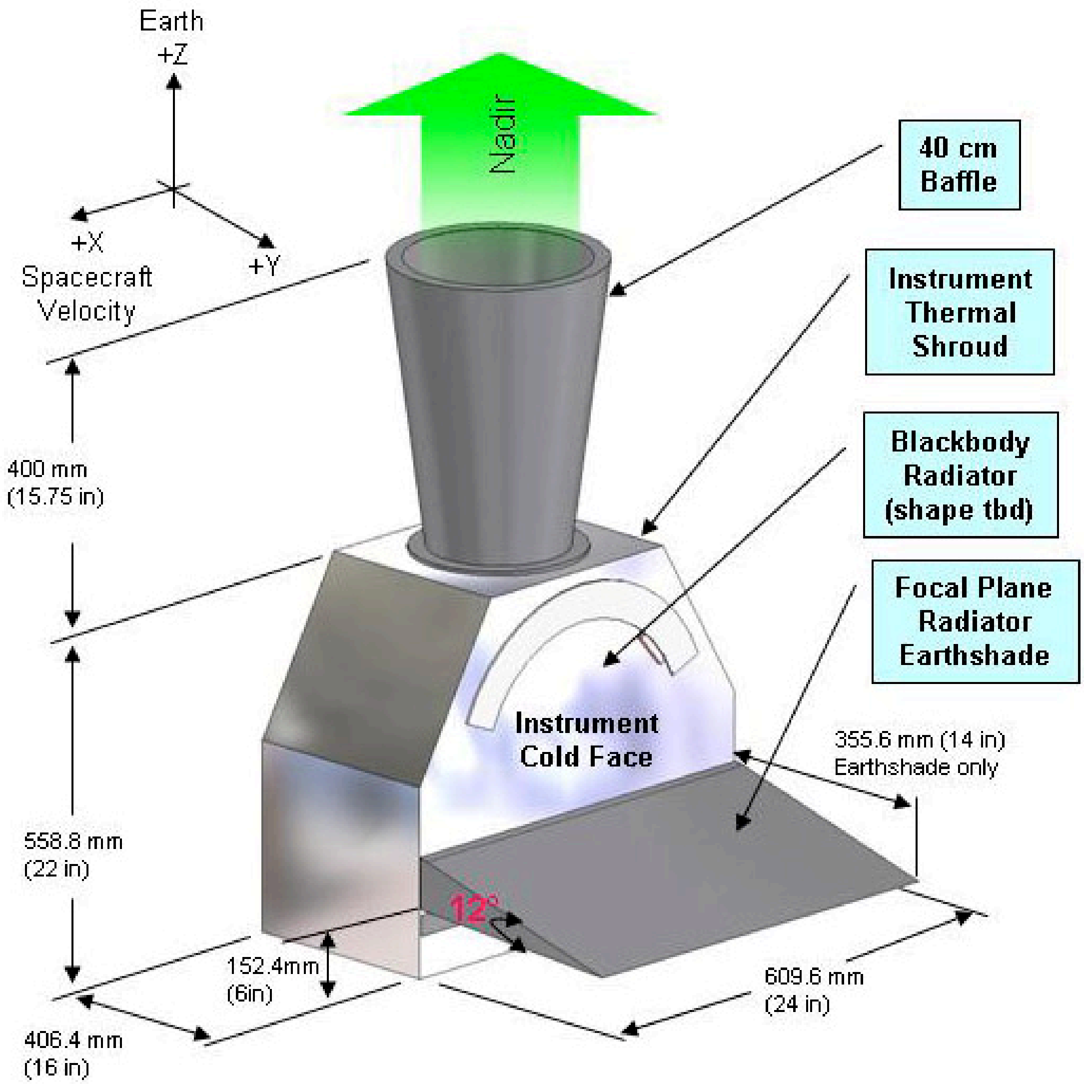
Figure 3-9. OLI Optical Bench Mounting Orientation

IRD-1949 The OLI mounting interfaces to the spacecraft shall be specified in the ICD by the spacecraft contractor.

3.4.1.8.3 TIRS Mounting Provisions

IRD-1650 The compatible mounting interfaces of the TIRS instrument shall be either the -X, +X, -Y, or -Z face of the instrument as represented in Figure 3-10.

TIRS images in +Z (nadir).



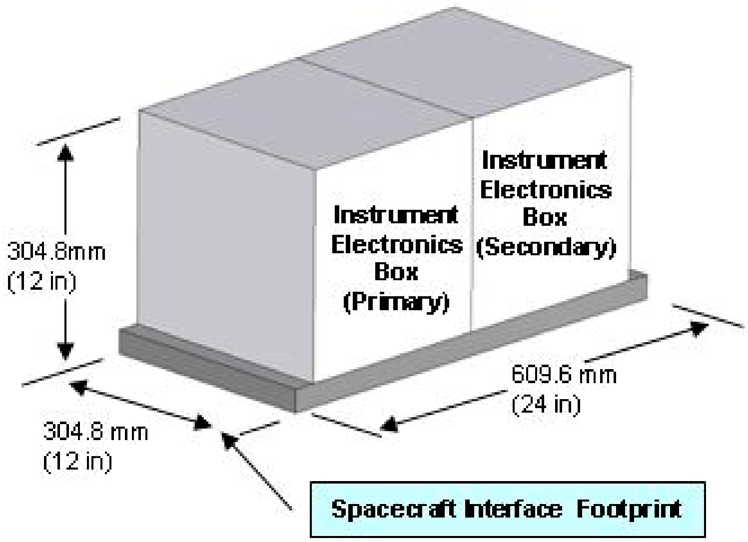


Figure 3-10. TIRS Instrument Mounting Orientation & Footprints

IRD-1809 The TIRS mounting interfaces to the spacecraft shall be specified in the ICD by the spacecraft contractor.

3.4.1.8.4 TSIS Mounting Provisions

IRD-1913 The spacecraft shall provide a mounting interface for TSIS with a coefficient of expansion similar to that of aluminum.

Rationale:

TSIS gimbal assembly is nearly all aluminum.

IRD-1915 The TSIS mounting interfaces to the spacecraft shall be specified in the ICD by the spacecraft contractor.

3.4.1.8.5 Instrument Structural Support

IRD-206 The spacecraft shall establish not-to-exceed interface limit loads based upon the Mass Acceleration Curve (MAC) for components as shown in Figure 3-11, until a combined launch vehicle and Observatory coupled loads analysis is completed.

Rationale:

These loads represent the quasi-static loads due to the low-frequency launch environment. The hardware should be designed for the loads given below as well as for loads induced by the high-frequency random environment. The breakpoints for the MAC are given in Table 3-4. Design *loads shown below should be updated based on the results of coupled loads analysis. Linear interpolation may be used between break-points to determine limit load.*

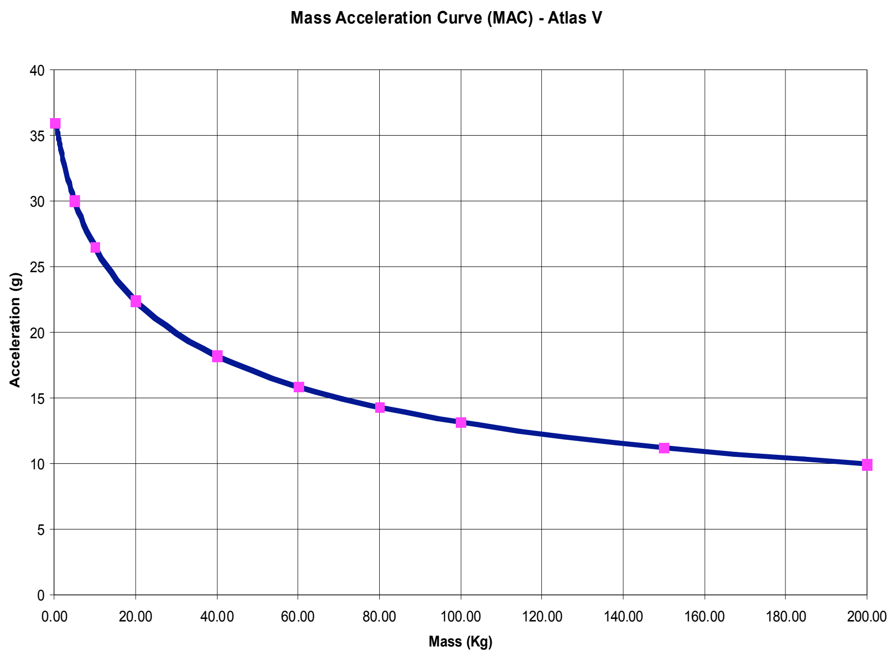


Figure 3-11. Component Mass Acceleration Curve (MAC)

Table 3-4. Component Design Loads (Break Points)

Component Mass (kg)	Limit Load (G, Any Direction)
1.0 or less	36.0
5	30.1
10	26.5
20	22.4
40	18.2
60	15.9
80	14.3
100	13.2
150	11.2
200 Kg. or Greater	10.0

IRD-207 The spacecraft contractor shall provide sufficient structural support for the instruments such that the loads transmitted through the instrument deck and across the interface do not exceed these interface limit loads.

IRD-1742 Instrument structural support components shall be designed to show positive margin for limit load using FS=1.25 for yield and FS=1.4 for ultimate.

IRD-1743 Instrument structural support components shall be tested to 1.25 times the limit load in 3 mutually perpendicular axes.

3.4.1.8.6 AOCS Sensor Accommodation

IRD-209 The instrument deck shall accommodate AOCS sensors such as gyros and star trackers.

Rationale:

It is expected that the spacecraft will need to place AOCS sensors on the instrument deck in order to meet the pointing requirements.

3.4.1.8.7 Instrument Mounting Method

IRD-212 The mounting method for the instrument to the instrument deck shall accommodate manufacturing tolerance, structural distortion, thermal distortions, distortion due to moisture absorption, and alignment requirements.

Rationale:

T*he instrument deck to instrument mounting interface will be established by the spacecraft contractor from the instrument provided drill template and shown in each instrument MID. This process aligns the instrument mechanical datums to the spacecraft body frame within the spacecraft alignment control allocation precluding the need to shim or correct the instrument orientation at instrument installation.*

If required, the spacecraft contractor will provide contingency shims to correct instrument alignment control error at installation. Shim capability for out of plane rotations (spacecraft X & Y axis) will be limited by pin / bolt clearance. There is no adjustment capability for in plane rotation (about spacecraft Z axis) where close fit pins are used.

Potential mounting interface gaps (prior to fastener any preload) will be managed through instrument, spacecraft, and drill template flatness and / or co-planarity requirements to preclude the need to shim for gaps at installation.

If required, the spacecraft contractor will provide contingency shims to close gaps at installation. Shim capability will be limited by pin/bolt clearances and access required to inspect or perform gap measurements.

IRD-217 The instrument mounting method shall require access only from outside the spacecraft.

IRD-218 Specific requirements for pinning the instrument, if required, shall be documented in each instrument to spacecraft ICD, by the spacecraft contractor.

3.4.1.8.8 Mounting Interface

3.4.1.8.8.1 Mounting Interface Documentation

IRD-221 The spacecraft mounting interface requirements for each separately-mountable instrument component shall be defined in each instrument MID.

3.4.1.8.9 Drill Templates

3.4.1.8.9.1 Drill Template Usage

The drill template is used during the manufacturing of the spacecraft bus to establish instrument interface features. The drill template is supported from a gantry (mechanical ground support equipment). The template/instrument mounting datum features are aligned to the spacecraft body frame with laser tracker and/or theodolite measurements. With the template properly aligned, spacecraft secondary structure is matched to the template through a combination of drill, bolt, and bonding processes as required.

The drill template may also be used for interface and alignment verification during the spacecraft manufacturing and AI&T phases.

IRD-226 The OLI and TIRS instrument to instrument deck, and instrument test fixture interfaces shall be established using drill templates (i.e. face to face master).

3.4.1.8.9.2 Drill Template Fabrication Requirements

IRD-228 Drill template design features (including, but not limited to surface flatness, surface finish, surface treatment, etc.) shall be documented in each instrument MID by the instrument contractor or provider.

IRD-230 Drill templates for each component that require alignment shall include an optical alignment target or cube bonded to the template.

IRD-231 Optical alignment target / cube nominal location and orientation on the drill template with respect to mounting datum(s), with alignment tolerances shall be shown on MID by the instrument contractor or provider.

IRD-232 Optical alignment target / cube nominal locations and orientations on the drill template with respect to mounting datum(s) shall be coordinated with instrument and spacecraft contractors.

3.4.1.8.10 Mounting Hardware

3.4.1.8.10.1 Mounting Hardware Provider

IRD-235 The instrument contractor shall provide all unique instrument mounting hardware (e.g., bolts, washers, pins, etc. which have limited-off-the-shelf availability or require a special fabrication lot).

IRD-236 The spacecraft contractor shall provide all standard instrument mounting hardware (e.g., bolts, washers, shims, etc. which are procurable off-the-shelf from multiple hardware vendors).

3.4.1.8.10.2 Mounting Hardware Documentation

IRD-238 Instrument mounting hardware shall be defined and documented in each instrument MID, including indication of the source of the hardware (spacecraft or instrument).

3.4.1.8.10.3 Mounting Surface Requirements

IRD-243 Finish requirements for the instruments' mounting surfaces shall be specified by the spacecraft contractor and documented in the ICD by the spacecraft contractor.

IRD-244 The spacecraft mounting surface flatness shall be documented in the ICD by the spacecraft contractor.

IRD-245 The instrument mounting surface flatness shall be documented in each instrument MID by the instrument contractor or provider.

IRD-246 The spacecraft mounting surface planarity shall be documented in the ICD by the spacecraft contractor.

IRD-247 The instrument mounting surface planarity shall be documented in each instrument MID by the instrument contractor or provider.

3.4.1.8.11 Mounting Location and Documentation

IRD-249 The instrument contractors or providers shall support the spacecraft contractor in determining the location of the instruments' on the spacecraft.

IRD-250 The instrument contractors or providers shall provide mounting information via a MID to the spacecraft contractor.

IRD-251 The instrument mounting location on the spacecraft shall be documented in the ICD by the spacecraft contractor.

3.4.1.8.12 Instrument Mounts

IRD-253 The instrument deck shall accommodate the mounting of critical instrument components (support electronics boxes) within the instruments allocated volume.

Rationale:

Certain instrument electronic boxes (i.e. OLI FPE) must be mounted within 25.4 centimeters of the instrument. Other electronics may be mounted at a convenient location on the spacecraft.

3.4.2 Orbit Control, Pointing and Alignment

Pointing: The process of controlling the location or direction of a Line of Sight with respect to an intended target location or direction.

Instrument Interface: The mechanical interface and associated datum(s) at the location where the instrument attaches to the spacecraft.

Jitter: Uncontrolled rotational and translational disturbances at the instrument(s) interface.

Spacecraft Attitude Determination Frame: The right-handed orthogonal reference frame which approximates the Spacecraft Body Frame and of which the Attitude Determination System on board the spacecraft determines inertial attitude. For LDCM, the datums associated with the Spacecraft Control Frame will be defined by the spacecraft contractor. The Spacecraft Attitude Determination Frame is defined by the relative orientation of these datums with respect to the Spacecraft Body Frame, as established by measurements during installation alignment or on-orbit calibration.

<u>Spacecraft Target Frame</u>: The right-handed, orthogonal reference frame that, at any time, is the target attitude of the Spacecraft Attitude Determination Frame.

<u>3 Sigma</u>: A set of values with a standard distribution is considered to meet a 3 sigma requirement if no fewer than 99.73% of the values are within the specified limits of the requirement.

<u>Root Sum Square (RSS):</u> The square root of the sum of the squares of components of error or uncertainty.

<u>Alignment:</u> The relative orientation of 2 reference frames.

<u>Installation Alignment:</u> The process of setting, measuring and/or adjusting the relative orientation of an instrument or hardware reference frame with respect to another reference frame in order to satisfy required alignment criteria.

<u>Alignment Shift:</u> A change in the alignment between 2 reference frames that occurs over one finite, defined, period of time, typically prior to and not changing significantly during normal on-orbit operations. For the alignment of the instruments relative to the spacecraft, alignment shifts arise from structural distortion effects such as launch loads, moisture out-gassing and the relief of gravity loads.

<u>Alignment Drift</u>: Changes in the alignment between 2 reference frames that occur during normal on-orbit operations, excluding effects due to jitter. For the alignment of instruments relative to the spacecraft, one source of drift is structural distortions arising from orbital and seasonal changes in thermal conditions.

<u>Alignment Knowledge</u>: The estimate of the relative orientation between 2 reference frames.

<u>Alignment Knowledge Uncertainty</u>: The uncertainty in the knowledge of the relative orientation between 2 reference frames.

<u>Boresight Alignment Knowledge Uncertainty:</u> For a specific instrument, the uncertainty in the knowledge of the relative orientation between its Instrument Boresight and the Spacecraft Attitude Determination Frame. This uncertainty will be considered to be composed of the following factors:

- *<u>Static Alignment Knowledge Uncertainty</u> (not changing significantly during normal on orbit operations)*

    Measurement uncertainty during installation alignment.
    Alignment Shifts.

 Dynamic Alignment Knowledge Uncertainty (changing significantly during normal on orbit operations)

Alignment Drifts.
Jitter.

Alignment Control: The process of controlling the maximum difference between the actual orientation of a reference frame and its nominal orientation.

Alignment Control Error: The maximum difference between the actual orientation of a reference frame and its nominal orientation.

Boresight Alignment Control Error: For a specific instrument, the maximum difference between the actual and the nominal orientation of its Instrument Boresight relative to the Spacecraft Attitude Determination Frame. This error will be considered to be composed of the following factors:

 Static Alignment Control Error (not changing significantly during normal on orbit operations)
Measurement uncertainty during installation alignment.
Limitations associated with fabrication and installation.
Alignment Shifts.

 Dynamic Alignment Control Error (changing significantly during normal on orbit operations)
Alignment Drifts.
Jitter.

3.4.2.1 Orbit Control

3.4.2.1.1 Spacecraft State Knowledge

IRD-316 The spacecraft shall supply to the ground an estimate of Spacecraft position and velocity for ground processing.

IRD-317 The spacecraft shall use Universal Time Coordinated (UTC) time as the observatory time reference.

IRD-318 The spacecraft shall provide the orbital position and velocity in the Earth Centered Inertial of epoch J2000.0 coordinate frame.

IRD-319 The spacecraft shall provide orbital position and velocity estimates time-tagged to an accuracy of 50.0 microseconds, 3-sigma, or less, with a frequency of at least once per second.

Rationale:

Constrains the timing-induced along-track position knowledge error due to the orbital velocity to be less than 0.5 meters (i.e., insignificant).

IRD-320 The spacecraft shall provide orbital position knowledge accurate to 30 m radial, 30 m in-track, and 30 m cross-track - all values are 3-sigma.

Rationale:

Position and velocity error is a significant term in the geolocation error budget. Accuracy somewhat better than this is required to achieve the OLI absolute geodetic accuracy requirement with margin but this level of real-time performance is sufficient to allow for the necessary improvement in post-processing.

IRD-321 The spacecraft shall provide orbital velocity knowledge accurate to 0.3 m/sec radial, 0.3 m/sec in-track, and 0.3 m/sec cross track - all values are 3-sigma.

Rationale:

Limits the accumulation of along-track error within a scene to be less than 0.5 panchromatic pixels.

IRD-1727 The spacecraft shall include the GPS observables (pseudo-range, carrier phase) in the observatory ancillary data and housekeeping telemetry.

Rationale:

Requested by the OLI vendor to allow for ground post-processing to achieve improved position and velocity knowledge.

3.4.2.2 Pointing

3.4.2.2.1 Spacecraft Attitude Knowledge

IRD-324 The spacecraft shall supply to the ground an estimate of Spacecraft's inertial attitude for ground processing.

IRD-325 The spacecraft shall provide the attitude estimate relative to the Earth Centered Inertial of epoch J2000.0 coordinate frame.

IRD-326 The spacecraft shall provide inertial attitude knowledge of the spacecraft attitude determination frame with an accuracy of 109 micro-radians, 3-sigma, per axis, during imaging.

Rationale:

Attitude knowledge error is the most significant term in the geolocation error budget. Accuracy somewhat better than this is required to achieve the OLI absolute geodetic accuracy requirement with margin but this level of real-time performance is sufficient to allow for the necessary improvement in post-processing.

IRD-1356 The spacecraft shall provide inertial attitude knowledge of the spacecraft attitude determination frame with an accuracy of 218 micro-radians, 3-sigma, per axis, during lunar calibration.

Rationale:

The OLI Earth point accuracy requirement which drives the attitude knowledge requirement does not apply to lunar calibration acquisitions so the knowledge requirement is relaxed to accommodate the non-standard pointing configuration.

IRD-327 The spacecraft shall provide an estimate of the inertial attitude knowledge time-tagged to an accuracy of 150.0 microseconds, 3-sigma, or less, with a frequency of at least once per second.

Rationale:

Constrains the timing-induced along-track attitude knowledge error due to the orbital pitch rate to be less than 0.1 microradian (i.e., insignificant).

IRD-328 The spacecraft shall provide relative inertial attitude knowledge accuracy over a 30 second period of 9 micro-radians or less, 3-sigma, per axis, during imaging.

Rationale:

Must maintain relative attitude knowledge over the time span of a scene to ensure image internal geometric accuracy and achieve image-to-image registration requirements.

IRD-329 The spacecraft shall provide relative inertial attitude knowledge accuracy over a 2.5 second period of 5 micro-radians or less, 3-sigma, per axis, during imaging.

Rationale:

Must maintain relative attitude knowledge over the time span required to image all reflective bands to ensure band-to-band registration accuracy.

IRD-1732 The spacecraft shall include the unprocessed spacecraft attitude determination sensor (e.g., IRU, star tracker) observations in the observatory ancillary data stream, for use in ground processing of OLI data.

Rationale:

To improve upon the real-time attitude knowledge by performing post-pass attitude filtering in ground processing.

IRD-330 The spacecraft shall supply to the ground the attitude and/or attitude rate measurements, at the full attitude sensor (star tracker, IRU) data rate, for ground processing of OLI data.

Rationale:

The reported attitude sensor sampling rate need not exceed the maximum rate for each device.

The downlinked ancillary data must reflect the full bandwidth of the onboard attitude sensors to avoid aliasing errors or unnecessary smoothing in the reconstruction of the spacecraft attitude time history on the ground. Thus, full rate attitude sensor data are required.

3.4.2.2.2 Spacecraft Attitude Control

During normal operation, the Spacecraft Attitude Control Error is the difference between the orientation of the Spacecraft Target Frame and the orientation of the Spacecraft Attitude Determination Frame. During normal operation, the Spacecraft Attitude Control Rate Error is the difference between the angular rate of the Spacecraft Target Frame and the angular rate of the Spacecraft Attitude Determination Frame.

IRD-333 The LDCM Observatory pointing reference shall be with respect to the LDCM Orbital Reference Frame as defined in IRD-138.

IRD-334 The spacecraft shall limit pointing control error to less than 525 micro-radians, 3-sigma, per axis, during imaging periods.

IRD-425 The LDCM spacecraft shall provide autonomous yaw steering to maintain the spacecraft body frame +X direction parallel to the ground velocity vector.

Rationale:

The capability to orient the spacecraft body frame relative to the ground velocity vector rather than the inertial velocity vector (by compensating for Earth rotation effects) will simplify the design of a pushbroom sensor payload and the associated data processing by nominally aligning pixel columns with the spacecraft ground track. This minimizes the problems with sideslip that can arise when detector elements are staggered in the along-track direction.

This is an absolute requirement and applies to all imaging periods of any duration. Only the relative requirements are assigned time periods since they relate the attitude at any given time (T) to the attitude at an earlier time (T - time period). Absolute requirements do not need an imaging period as a reference.

IRD-335 The spacecraft shall limit pointing rate error to less than 145 micro-radians/sec, 3-sigma, per axis, during imaging periods.

Rationale:

This is an absolute requirement and applies to all imaging periods of any duration.
Limit the misalignment between image pixels from adjacent even and odd detectors (separated by up to 6 IFOVs along-track) due to attitude rate errors, to be less than 0.1 pixels.

3.4.2.2.3 Spacecraft Attitude Control - Following Eclipse Exit

IRD-1671 The spacecraft shall limit pointing control error during the first 3 minutes after eclipse exit and the first 3 minutes after eclipse entrance to less than 791 micro-radians, 3-sigma, per axis.

Rationale:

Accommodate short term attitude disturbances due to thermal snap following sun and eclipse exposure. Imaging may occur during eclipse transition periods.

IRD-1670 The spacecraft shall limit pointing rate error during the first 3 minutes after eclipse exit and the first 3 minutes after eclipse entrance to less than 217.5 micro-radians/sec, 3-sigma, per axis.

Rationale:

Accommodate short term attitude disturbances due to thermal snap following sun and eclipse exposure. Imaging may occur during eclipse transition periods.

3.4.2.2.4 Translational Disturbance Environment

The baseline spacecraft translational accelerations for each axis at the OLI interface is approximated by the single-sided power spectral density (PSD) curve specified in Table 3-5, and shown in Figure 3-12. The PSD is defined from 0.1 to 1000 Hz. A single-sided PSD, consisting of positive frequencies only, is specified, in which PSD levels are assumed to be composed of contributions at both positive and negative frequencies so that summing over positive frequencies results in the total energy. The allowable disturbance environment is subject to refinement in the ICD based on a detailed spacecraft-instrument jitter analysis. To this end, the instrument contractor will provide a finite element model (FEM) to the spacecraft contractor per the SOW for end-to-end modeling of LOS motion.

IRD-1360 The spacecraft translational acceleration disturbance, for each axis, at the OLI interface shall not exceed the PSD curve specified in Table 3-5 and shown in Figure 3-12, except as defined in the following requirements.

Rationale:

Jitter-induced line-of-sight variations contribute to geolocation and band registration errors, to the extent they are unmeasured, and to image smear, whether measured or not. The OLI is particularly sensitive to jitter above 50 Hz as this is beyond the bandwidth of typical inertial reference units and, hence, is unmeasured, and begins to overlap the region of allowable instrument structural modes, which can amplify the jitter to line-of-sight transfer.

IRD-338 The actual spacecraft translational acceleration interface disturbance PSD is allowed to have peaks that cross the curve shown in Figure 3-12, but these peaks shall not excite instrument resonance modes.

Rationale:

An instrument mode is considered excited by a disturbance peak if the disturbance peak overlaps a portion of the instrument mechanical response where the gain is greater than 1.

Individual disturbance peaks that exceed the PSD thresholds will not cause unacceptable pointing disturbances so long as they are not amplified by resonance in the instrument structure.

IRD-339 The total energy within a frequency band of the spacecraft translational disturbance environment shall not exceed the levels specified in Table 3-6.

Rationale:

The actual spacecraft disturbance spectrum is expected to include local peaks associated with particular sources. Even if one or more of these peaks exceed the disturbance PSD specification curve, they will not create unacceptably large disturbances so long as: 1) they do not excite with instrument modes; and 2) the total disturbance in each frequency band is not exceeded.

Table 3-5. Spacecraft Translational Disturbance Environment

Frequency (Hz)	Translational Acceleration PSD $((mg)^2/Hz)$
0.1	10
1	10
10	0.10
50	8E-4
100	2E-3
1000	1.0

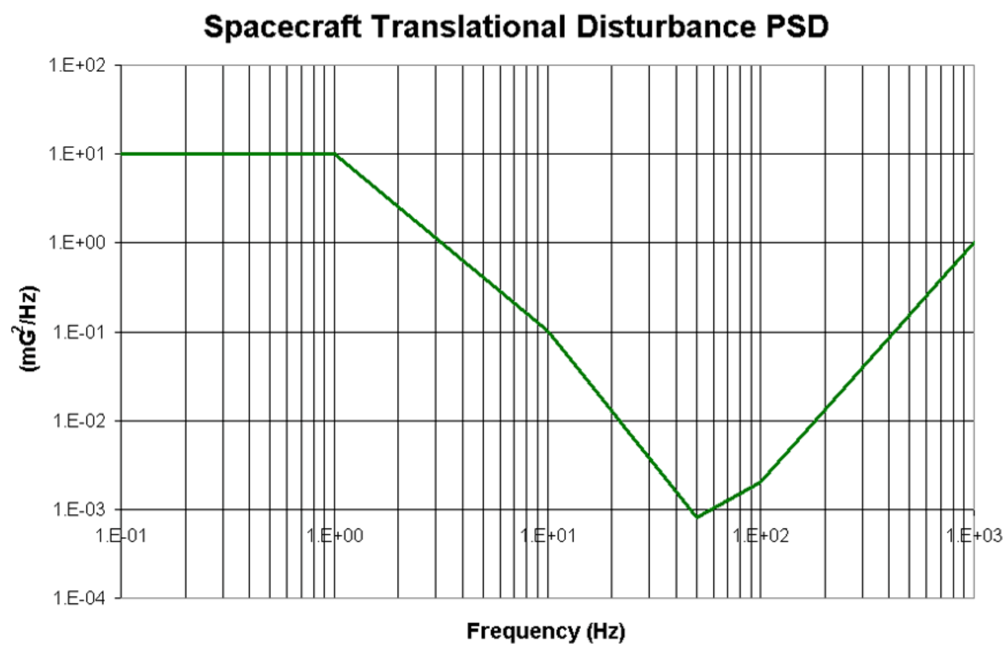


Figure 3-12. Spacecraft Translational Disturbance Environment

Table 3-6. Spacecraft Translational Disturbance Allowable Energy

Frequency Range (Hz)	Energy $((mg)^2)$
0.1 - 1	9.1
1 - 10	9.1
10 -50	0.49
50 -100	0.07
100-1000	270

3.4.2.2.5 Rotational Disturbance Environment

The baseline spacecraft rotational disturbances about each axis at the OLI interface is approximated by the power spectral density (PSD) curve specified in Table 3-7, and shown in Figure 3-13. The PSD is defined from 0.1 to 1000 Hz. The allowable disturbance environment is subject to refinement in the ICD based on a detailed spacecraft-instrument jitter analysis. To this end, the instrument contractor will provide a finite element model (FEM) to the spacecraft contractor per the SOW for end-to-end modeling of LOS motion.

IRD-1373 The spacecraft rotational disturbance, for each axis, at the OLI interface shall not exceed the PSD curve specified in Table 3-7 and shown in Figure 3-13, except as defined in the following requirements.

Rationale:

Jitter-induced line-of-sight variations contribute to geolocation and band registration errors, to the extent they are unmeasured, and to image smear, whether measured or not. The OLI is particularly sensitive to jitter above 50 Hz as this is beyond the bandwidth of typical inertial reference units and, hence, is unmeasured, and begins to overlap the region of allowable instrument structural modes, which can amplify the jitter to line-of-sight transfer.

IRD-939 The actual spacecraft interface rotational disturbance energy is allowed to have peaks that cross the curve shown in Figure 3-13, but these peaks shall not excite instrument resonance modes.

Rationale:

An instrument mode is considered excited by a disturbance peak if the disturbance peak overlaps a portion of the instrument mechanical response where the gain is greater than 1.

Individual disturbance peaks that exceed the PSD thresholds will not cause unacceptable pointing disturbances so long as they are not amplified by resonance in the instrument structure.

IRD-383 The total energy within the frequency bands of the spacecraft rotational disturbance environment shall not exceed the levels specified in Table 3-8.

Rationale:

The actual spacecraft disturbance spectrum is expected to include local peaks associated with particular sources. Even if one or more of these peaks exceed the disturbance PSD specification curve, they will not create unacceptably large disturbances so long as: 1) they do not excite instrument modes; and 2) the total disturbance in each frequency band is not exceeded.

Table 3-7. Spacecraft Rotational Disturbance Environment

Frequency (Hz)	Rotation PSD (_rad^2/Hz)
0.1	2500
1	25
10	2.5E-3
50	4E-6
100	1E-6
1000	1E-7

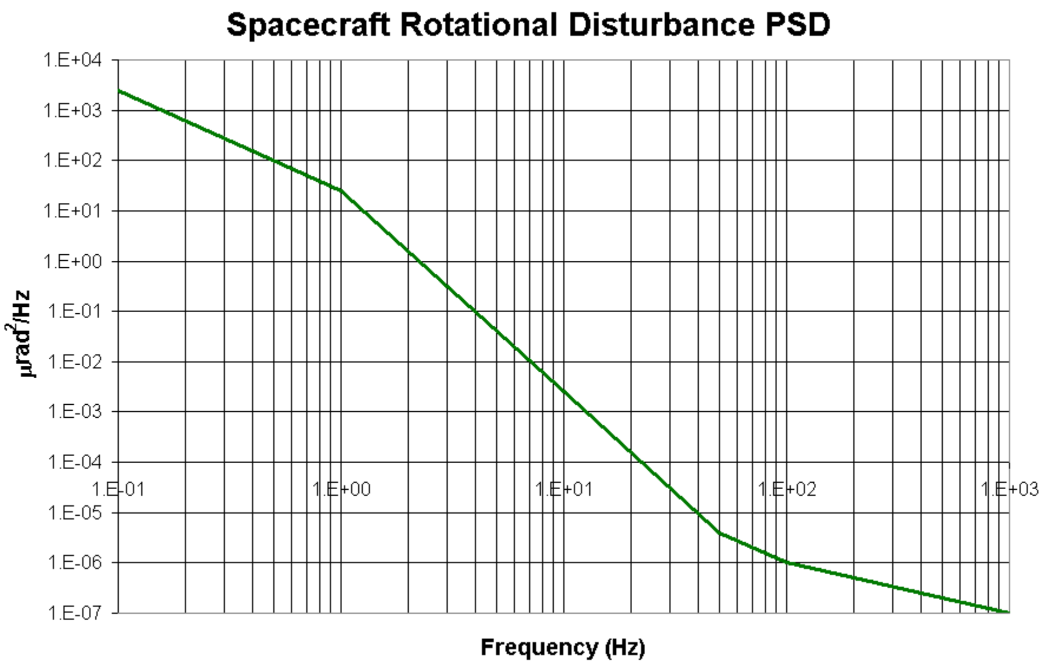


Figure 3-13. Spacecraft Rotational Disturbance Environment

Table 3-8. Spacecraft Rotational Disturbance Allowable Energy

Frequency Range (Hz)	Energy (_rad^2)
0.1 - 1	225
1 - 10	8.3
10 -50	8.3E-3
50 -100	1.0E-4
100 -1000	2.3E-4

The jitter is assumed to have a zero-mean Gaussian distribution so root-mean-square jitter magnitudes computed by integrating the PSD and taking the square root, correspond to 1-sigma *values. So, for example, the integrated energy values in the last three rows of Table 3-8 sum to an equivalent 3-sigma jitter limit above 10 Hz of 0.28 micro-radians.*

3.4.2.3 Alignment

3.4.2.3.1 Installation Alignment Responsibilities

IRD-429 The instrument contractor shall provide an Instrument Alignment Reference(s) composed of an alignment target or cube with associated alignment data relative to the Instrument Boresight and the mounting surface datum(s) associated with the instrument.

IRD-430 The spacecraft contractor shall provide a Spacecraft Alignment Reference(s) composed of an alignment target or cube with associated alignment data relative to the Spacecraft Body Frame.

IRD-431 The instrument contractor or provider shall provide alignment data for the Instrument Boresight relative to the Instrument Alignment Reference(s) to the spacecraft contractor.

IRD-432 The spacecraft contractor shall measure the alignment between the Instrument Alignment Reference and the Spacecraft Alignment Reference.

3.4.2.3.2 Installation Alignment References

IRD-434 The Instrument Alignment References shall be viewable from two orthogonal directions when integrated to the Observatory.

IRD-435 The type, location, and orientation of the Instrument Alignment References will be mutually agreed upon between the instrument contractors and the spacecraft contractor, and shall be documented in the ICD by the spacecraft contractor.

IRD-436 Optical targets or cubes shall have a per-face surface area of at least 360 mm^2.

IRD-437 At least two viewing surfaces of the optical alignment target or cube shall be orthogonal to within ± 15 micro-radians, 3 sigma.

IRD-438 Each optical target or cube shall be covered with a flight quality (and flight capable) cover.

IRD-439 The optical cube cover shall be removable during Integration and Test.

IRD-440 The optical cube cover shall be installed prior to integration onto the launch vehicle.

IRD-441 The cover shall provide captive hardware to prevent loose pieces if the cube comes loose.

3.4.2.3.3 Alignment Knowledge

IRD-443 The spacecraft shall provide Boresight Alignment Knowledge between the Spacecraft Attitude Determination Frame and the Instrument Interface (mounting surface datums) with an accuracy ≤2 milliradians (3-sigma), per axis.

Rationale:

The alignment between the instrument boresight and the spacecraft attitude determination frame will be measured on-orbit to much higher accuracy but pre-launch knowledge is required to be sufficient to initiate the on-orbit process and to ensure that the alignment control requirements have been met.

IRD-444 All components of Boresight Alignment Knowledge Uncertainty between the Instrument Interface (mounting surface datums) and the Instrument Boresight shall be documented in the ICD by the spacecraft contractor.

IRD-445 Components of Boresight Alignment Knowledge Uncertainty resulting from alignment shifts allowed by clearances across the mounting interface (pin/fastener to hole tolerance) at the Instrument Interface (mounting surface datums) will be allocated to the instrument, and shall be documented in the ICD by the spacecraft contractor.

3.4.2.3.4 Alignment Control

IRD-447 The spacecraft shall provide Boresight Alignment Control between the Spacecraft Attitude Determination Frame and the Instrument Interface (mounting surface datums) to an accuracy of 5 milliradians (3-sigma), per axis.

Rationale:

The instrument boresight must be sufficiently aligned with the spacecraft attitude determination frame to limit the difference between the spacecraft ground track and the instrument swath center to be less than the orbit control error (3-5 km) and to limit yaw-steering errors.

IRD-448 For each instrument, the Boresight Alignment Control Error is controlled by an allocation from the Instrument Boresight to the Instrument Interface mechanical datums, as well as an allocation from the Instrument Interface mechanical datums to the Spacecraft Attitude Determination Frame, and shall be documented in the ICD by the spacecraft contractor.

IRD-449 For each instrument, the Boresight Alignment Control Error allocations shall be documented in the ICD by the spacecraft contractor.

IRD-451 Components of Boresight Alignment Control Error resulting from alignment shifts allowed by clearances across the mounting interface (pin/fastener to hole tolerance) at the Instrument Interface (mounting surface datums) are allocated to the instrument, and shall be documented in the ICD by the spacecraft contractor.

3.4.2.3.5 Alignment Stability

IRD-453 The spacecraft shall maintain alignment stability of 9 microradians or less, per axis, from the OLI mounting interface to the spacecraft attitude determination frame, over any period of 30 seconds.

Rationale:

Short-term alignment stability along with short-term attitude knowledge are required to achieve image-to-image registration and internal geometric accuracy.

IRD-454 The spacecraft shall maintain alignment stability of 30 microradians or less, per axis, from the OLI mounting interface to the spacecraft attitude determination frame, over any period of 16 days.

Rationale:

The OLI to SADF alignment must be stable over the minimum recalibration period (16-days) to ensure that the OLI absolute geodetic accuracy requirements are met.

IRD-455 The spacecraft shall maintain alignment stability of 28 (TBR) microradians or less, per axis, from the TIRS mounting interface to the OLI mounting interface, over any period of 16 days.

Rationale:

OLI to TIRS alignment stability over the minimum recalibration period (16-days) is required to ensure reflective to thermal band registration accuracy.

3.4.3 Thermal Interface Requirements

3.4.3.1 General

IRD-458 The operating and safe-hold/survival temperatures, as well as the thermal isolation requirements specified in this section shall be met at the mechanical interface between the spacecraft and the instrument.

IRD-459 The instrument thermal design shall provide for utilizing spacecraft safe-hold/survival bus power for maintaining the instrument at or above the minimum survival temperature when the instrument is off (including launch configuration) and at or above the minimum turn-on temperature before the instrument is activated.

3.4.3.2 Thermal Recovery

IRD-942 The instrument shall take no more than 4 hours to return from safe-hold/survival mode to a temperature condition capable of normal operation, after spacecraft application of operational power.

Rationale:

This time limitation does not include passive radiative detector coolers.

3.4.3.3 Instrument Thermal Fields of View

IRD-461 Thermal analysis will verify the heat transfer adequacy at the final mounting locations for the instruments. Details of adjacent hardware within the instruments' thermal FOV shall be provided by the spacecraft contractor to a mutually agreed upon level of fidelity.

3.4.3.3.1 OLI Thermal Fields of View

IRD-464 The spacecraft shall provide to the cold face of the OLI a minimally obstructed hemispherical FOV for heat dissipation, with a maximum thermal backload in accordance with Table 3-9 (TBR) and Figure 3-14 (TBR).

Table 3-9. Allowable Backload on OLI Radiators

Critical Radiator Surface	Faces To	Objects <170 K _ VF	Objects 170 to 290 K _ VF	Objects 290 to 330 K _ VF	Permissible Incident Reflected Solar Flux (W/sqM)
FPA Radiator	+Y	<0.10	<0.05	<0.01	<10
FPA Earthshield	N/A	≤1.00	<0.15	<0.05	<75
FPE Radiator	+Y	<0.20	<0.10	<0.02	<75
ISE Radiator	Any	≤1.00	<0.35	<0.15	<200

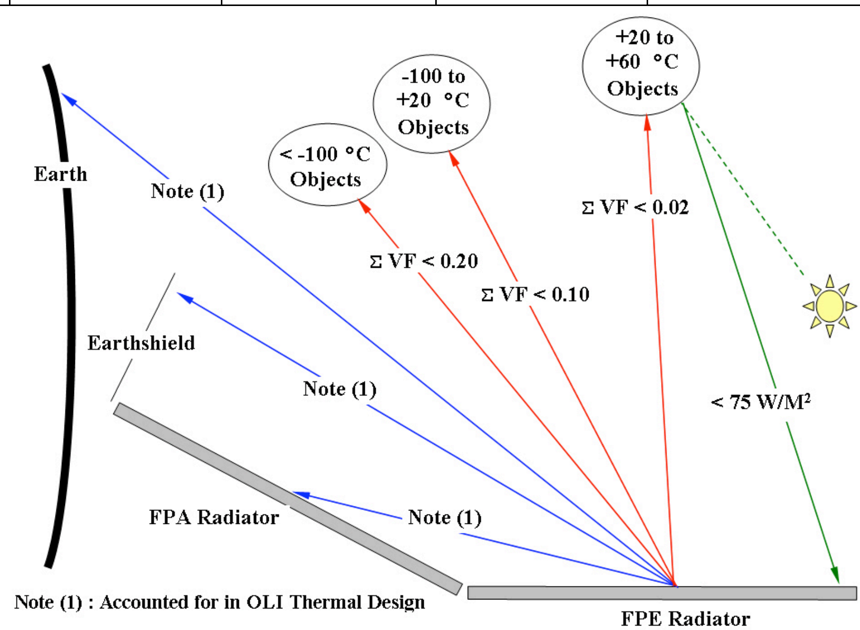


Figure 3-14. Allowable Backload on OLI Radiators

3.4.3.3.2 TIRS Thermal Fields of View

IRD-466 The spacecraft shall provide to the cold face of the TIRS a minimally obstructed hemispherical FOV for heat dissipation, with a maximum thermal backload of TBD.

3.4.3.3.3 TSIS Thermal Fields of View

IRD-1334 The spacecraft shall provide to the cold face of the TSIS a minimally obstructed hemispherical FOV for heat dissipation, with a maximum thermal backload of 77watts/m^2.

3.4.3.4 Heat Transfer

To maintain flexibility in the placement of the instruments on the spacecraft, it is necessary to limit the total heat transfer (conduction and radiation) to the spacecraft and other instruments. The thermal isolation is accomplished by minimizing thermal conduction and radiation using low thermal conductivity mechanical interface mounts and low effective emissivity MLI blankets at all non-radiator instrument surfaces. Radiation to the Earth or to cold space is intended to be the primary means of dissipating waste heat from the instrument.

IRD-469 The total orbit-average heat transfer rate (conducted and radiated) between the instrument and the spacecraft shall not exceed 10 watts into or out of the instrument mounting surface.

Rationale:

This includes heat conducted through the harness and ground straps.

IRD-471 The total orbit-average heat transfer rate between the OLI and any adjacent instrument shall not exceed 1 watt (TBR).

IRD-472 Each instrument module total orbit average heat transfer rate (conducted and radiated) between the instrument and the spacecraft, divided by the footprint area, shall not exceed 15 watts per square meter into or out of the instrument.

Rationale:

This includes heat conducted through the harness and ground straps.

The term 'footprint area" as used in this requirement means the area under the instrument module, projected onto the spacecraft. It does not refer to the area of the footprint of the instrument mounts.

3.4.3.5 Temperature

IRD-476 Temperature limits for instrument components during ground test and orbital operations shall be provided by the instrument contractors to the spacecraft contractor for documentation in the ICD.

IRD-477 Turn-on temperature requirements, relative to the passive analog temperature sensors, shall be provided by the instrument contractors to the spacecraft contractor for documentation in the ICD.

3.4.3.5.1 Spacecraft Mounting Interface Temperature Requirements

IRD-479 In normal operational mode, the spacecraft shall maintain the temperature of the mechanical instrument-to-spacecraft mounting surface (instrument deck) within the operating range of +15C to +25C (TBR).

IRD-480 The instrument shall meet all specified performance requirements when the temperature of the instrument-to-spacecraft mounting surface (instrument deck) is in the normal operating range of +15C to +25C (TBR).

IRD-481 The spacecraft shall maintain the temperature of the instrument-to-spacecraft mounting surface (instrument deck) interface to survival temperatures of -40C minimum and +40C maximum.

3.4.3.5.2 Temperature Monitoring

IRD-483 The spacecraft contractor shall document the location of the spacecraft-provided interface temperature monitoring sensors in the ICD.

IRD-484 The instrument contractor shall provide the location of all instrument contractor-supplied temperature sensors and calibration data to the spacecraft contractor for documentation in the ICD.

3.4.3.5.2.1 Mechanical Mounting Interface Temperature Monitoring

IRD-486 The spacecraft shall monitor and report the temperatures of the spacecraft at the instrument mechanical mounting interfaces in the spacecraft telemetry.

3.4.3.5.2.2 Instrument Temperature Monitoring

IRD-488 All critical instrument temperatures shall be reported by the instrument in the housekeeping telemetry data to the spacecraft.

3.4.3.6 Thermal Control Design

3.4.3.6.1 Thermal Control Hardware

IRD-491 The instrument contractor shall provide to the spacecraft contractor information on instrument-provided thermal control hardware for documentation in the ICD.

Rationale:

The responsibility for providing the thermal control hardware is defined in Table 3-10.

Table 3-10. Thermal Control Hardware Responsibility

Hardware	Responsibility
Safe-hold/survival heaters	Instrument Contractor
Instrument thermal control hardware, including blankets, louvers, and heat pipes	Instrument Contractor
Instrument-to-spacecraft interface operational and safe-hold/survival heaters, thermistors, thermostats	Spacecraft Contractor
Thermal close-out blankets to interface between the instrument thermal blankets and the spacecraft thermal blankets	Spacecraft Contractor
Instrument-to spacecraft interface MLI blankets	Spacecraft Contractor

3.4.3.6.2 Safe-hold/Survival Heaters

IRD-514 Instruments shall utilize safe-hold/survival heaters to maintain temperatures at or above minimum survival limits, when the operational power bus has been disconnected from the instrument.

IRD-515 Safe-hold/survival heaters shall not be required to provide heat when the operational bus is active to the instrument.

IRD-516 In agreement with the instrument contractor, the spacecraft contractor may elect to leave the safe-hold/survival heater bus powered during the initial phase of warm-up upon exit from safe-hold/survival mode, but the instrument shall be capable of achieving thermal control, once the operational power bus is activated, without use of the safe-hold/survival heaters.

3.4.3.6.2.1 Safe-hold/Survival Mode Orientation

IRD-518 The observatory orientation when the instruments are in safe-hold/survival mode shall be with the solar arrays sun facing.

IRD-947 The spacecraft shall keep the instrument radiators facing away from the sun in instrument safe-hold/survival mode.

3.4.3.6.3 Operational Heaters

IRD-520 When the instrument operational power bus is active, operational heaters located inside the instrument, and controlled by the instrument, shall be used for normal thermal control.

3.4.3.6.4 Multilayer Insulation

IRD-523 MLI used in thermal control design shall have the following provisions: venting, interfacing with spacecraft thermal control surfaces, and electrical grounding to prevent Electro-Static Discharge (ESD).

3.4.3.6.5 Surface Cleanliness

IRD-525 Thermal control surfaces shall be visibly clean or better once the instrument is integrated with the spacecraft.

3.4.4 Electrical Interface Requirements

This section specifies electrical interface allocations, characteristics, connections, and function for power and C&DH interfaces provided to the instrument(s) and requirements at this interface. The spacecraft system interface block diagram is depicted in Figure 3-15, and the spacecraft to instrument electrical interfaces are notionally shown in Figure 3-16. The SSR is represented as an integral part of the spacecraft bus and will be procured as part of the spacecraft bus.

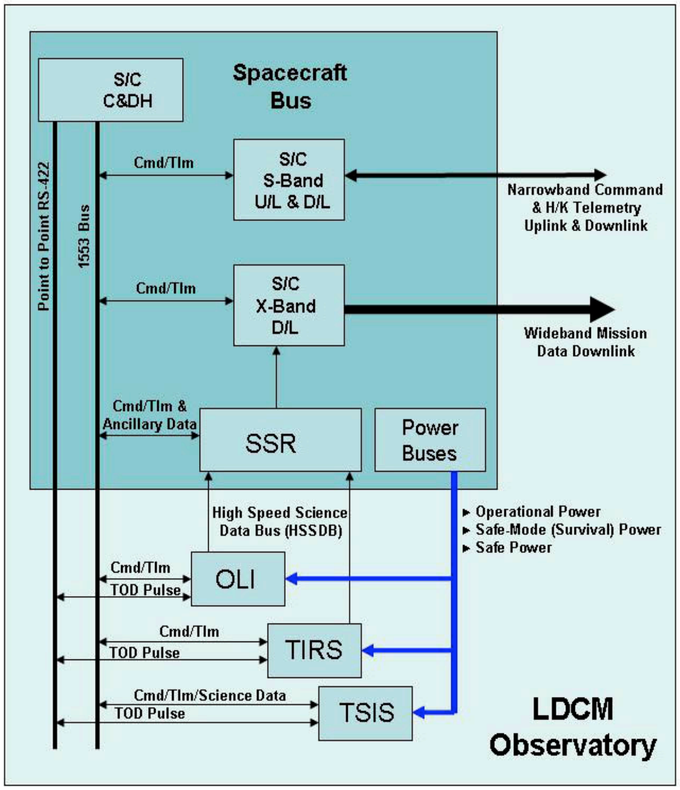


Figure 3-15. Spacecraft System Interface Block Diagram

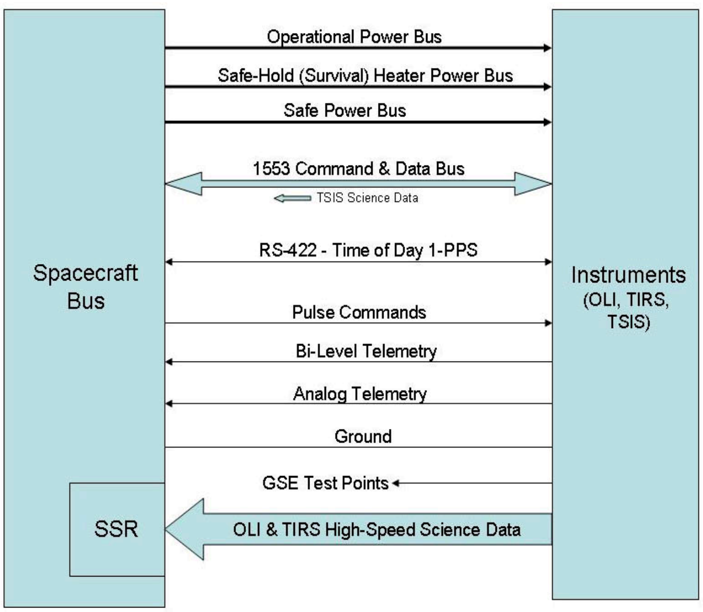


Figure 3-16. Spacecraft to Instrument Electrical Interfaces

3.4.4.1 Electrical Interfaces

IRD-673 The spacecraft provides the following electrical interfaces and services to the instruments.

- Operational Power Bus
- Safe-hold/survival Heater Power Bus
- Safe Bus
- High Speed Science Data Bus (HSSDB)
- 1553 Command and Data Bus
- 1 Hz Time of Day Pulse
- Pulse Command Interface
- Bilevel Telemetry Interface
- Passive Analog Telemetry Interface
- Grounding Interface
- Test Point Interface.

3.4.4.1.1 Interface Fault Tolerance

IRD-672 All electrical interfaces except test point interfaces shall be functionally redundant.

IRD-693 A single fault on either the spacecraft side of the interface or the instrument side of the interface shall not prevent the full and complete digital data transfer needed to fulfill mission requirements.

3.4.4.2 Power Allocation

Instrument power allocations (or "not to exceed") <u>include</u> margins that are in accordance with GSFC-STD-1000. The allocation includes the 30% above the current best estimate for each instrument. Additional margins (per Gold Rules) by the Spacecraft contractor are not required for instruments.

3.4.4.2.1 OLI Power Allocations

3.4.4.2.1.1 Operational Average Power Allocation

IRD-542 The orbital average OLI power consumed in operational modes shall be less than 200W.

3.4.4.2.1.2 Operational Peak Power Allocation

IRD-545 The peak OLI power consumed in operational modes shall be less than 375W.

3.4.4.2.1.3 Safe-hold/Survival Power Allocation

IRD-547 The OLI power consumed in safe-hold/survival mode shall be less than 150W (TBR).

IRD-548 The OLI safe-hold/survival heaters shall be sized using an assumed minimum spacecraft bus voltage of 25 V.

3.4.4.2.1.4 Launch-phase Power Allocation

IRD-550 The OLI power consumed in launch phase shall not exceed the safe-hold/survival mode power allocation.

3.4.4.2.1.5 Power Interface Allocation

IRD-553 The OLI contractor shall provide instrument power profiles for all instrument modes of operation for documentation in the ICD by the spacecraft contractor.

IRD-554 If the OLI power requirements vary as a function of orbit position, that duty cycle shall be supplied by the OLI contractor and documented in the ICD by the spacecraft contractor.

3.4.4.2.2 TIRS Power Allocations

3.4.4.2.2.1 Operational Average Power Allocation

IRD-557 The orbital average TIRS power consumed in operational modes shall be less than 200W (TBR).

3.4.4.2.2.2 Operational Peak Power Allocation

IRD-559 The peak TIRS power consumed in operational modes shall be less than 300W (TBR).

3.4.4.2.2.3 Safe-hold/Survival Power Allocation

IRD-561 The TIRS power consumed in safe-hold/survival mode shall be less than 150W (TBR).

IRD-562 The TIRS Safe-hold/Survival heaters shall be sized using an assumed minimum spacecraft bus voltage of 25 V.

3.4.4.2.2.4 Launch-phase Power Allocation

IRD-564 The TIRS power consumed in launch phase shall not exceed the safe-hold/survival mode power allocation.

3.4.4.2.2.5 Power Interface Allocation

IRD-567 TIRS shall provide instrument power profiles for all instrument modes of operation for documentation in the ICD by the spacecraft contractor.

IRD-568 If the TIRS power requirements vary as a function of orbit position, that duty cycle shall be supplied by the TIRS provider and documented in the ICD by the spacecraft contractor.

3.4.4.2.3 TSIS Power Allocations

3.4.4.2.3.1 Operational Average Power Allocation

IRD-1340 The orbital average TSIS power consumed in operational modes shall be less than 180W.

3.4.4.2.3.2 TSIS Operational Peak Power Allocation

IRD-1342 The peak TSIS power consumed in operational modes shall be less than 200W.

3.4.4.2.3.3 TSIS Safe-hold/Survival Power

IRD-1343 The TSIS power consumed in safe-hold/survival mode shall be less than 105W.

IRD-1351 The TSIS Safe-hold/Survival heaters shall be sized using an assumed minimum spacecraft bus voltage of 25 V

3.4.4.2.3.4 Launch Phase Power Allocation

IRD-1350 The TSIS power consumed in launch phase shall not exceed the safe-hold/survival mode power allocation.

3.4.4.2.3.5 Power Interface Allocations

IRD-1354 TSIS shall provide instrument power profiles for all instrument modes of operation for documentation in the ICD by the spacecraft contractor.

IRD-1355 If the TSIS power requirements vary as a function of orbit position, that duty cycle shall be supplied by the TSIS provider and documented in the ICD by the spacecraft contractor.

3.4.4.3 Power Control

3.4.4.3.1 Power Connections

IRD-571 Three supply circuit types shall be provided by the spacecraft, with preliminary allocations required by each instrument, plus spare services:

- 10 operational power connections (operational power bus) made through an appropriately-sized overcurrent protection device and switch, both on the spacecraft side of the interface.

OLI: 4 operational and 4 redundant
TIRS: 1 operational and 1 redundant
TSIS: 2 operational and 2 redundant
Spares: 3 operational and 3 redundant

- 6 power connections (safe-hold/survival heater bus) made through an appropriately-sized overcurrent protection device and a switch, both on the spacecraft side of the interface.

OLI: 1 safe-hold/survival heaters and 1 redundant
TIRS: 1 safe-hold/survival heaters and 1 redundant
TSIS: 2 safe-hold/survival heaters and 2 redundant
Spares: 2 safe-hold/survival heaters and 2 redundant

- 6 power connections (safe bus) of isolated power services to supply power for safety-related functions (fail-safe) such as explosive bolts, thermal release mechanisms, etc.

OLI: 2 fail safe (aperture shutter and diffuser) and 2 redundant
TIRS: 1 fail safe (calibration mechanism) and 1 redundant
TSIS: 1 fail-safe (deployment launch lock) and 1 redundant
Spares: 2 fail-safe and 2 redundant

IRD-575 Each power interface shall consist of redundant (isolated) power feeds routed via two separate connectors. These connections will be designated as power feeds A and B.

IRD-576 The nominal and maximum load currents for each power interface line, for each instrument mode, shall be provided by the instrument contractor and documented in the ICD by the spacecraft contractor.

IRD-577 The state of primary and redundant power services during normal operations shall be identified in the instrument telemetry.

Rationale:

If the power configuration is totally under the control of the spacecraft, no additional power status telemetry is needed from the instrument.

3.4.4.3.2 Power Application

IRD-580 In the absence of a fault (hardware, software, or operator) on either power service (i.e., an open fuse), the spacecraft shall apply power to neither operational power feed (instrument OFF) or a single operational power feed (instrument ON), but never to both operational power feeds simultaneously.

3.4.4.3.3 Power Fault Tolerance

IRD-582 The instrument and spacecraft shall not propagate a single fault occurring on either the A or B power interface circuit, on either side of the interface, to the redundant interface or instrument.

3.4.4.3.4 Instrument Heater Power Separation

IRD-584 Instrument safe-hold/survival heaters and operational heaters shall be separate and distinct, using separate electrical control, operating independently of each other.

3.4.4.3.5 Instrument Internal Power

IRD-586 Usage and distribution of primary power shall be compatible with system and subsystem Electromagnetic Compatibility (EMC) and magnetic field performance requirements.

IRD-587 Secondary power distribution to power components shall be compatible with system and subsystem EMC performance requirements.

3.4.4.3.6 Instrument External (Spacecraft) Power

IRD-589 Instruments shall be designed to operate from a 28 +7/-7 volt DC, negative ground, unregulated main bus power subsystem.

IRD-590 The spacecraft shall be able to remove bus power to all instruments if the spacecraft power system indicates an emergency energy imbalance. Exception: Removal of power shall not apply to safe-hold/survival heaters unless survival of the spacecraft is at stake.

3.4.4.3.7 Unannounced Removal of Power

IRD-592 Excluding the thermal effects of removing instrument power or damage that occurs as a result of leaving the instrument door open, unannounced removal of power shall not cause damage or degraded performance (following re-application of power) to the instrument.

Rationale:

The exclusion refers specifically to the fact that unannounced removal of ALL power (operational and safe-hold/survival) for an indefinite period could have permanent detrimental effects to the performance of the instrument.

3.4.4.4 Power Interface Requirements

See the LDCM Environmental Verification Requirements document for details on the operational bus electrical power interface environment.

3.4.4.4.1 Impedance

IRD-597 The power bus impedance shall be documented in the ICD by the spacecraft contractor.

IRD-598 The Q and impedance of the input filters of the instruments shall be provided by the instrument contractor and documented in the ICD by the spacecraft contractor.

3.4.4.4.2 Safe-Hold/Survival Heater Bus

IRD-600 The spacecraft shall provide to the instruments power for safe-hold/survival heaters, meeting the same voltage range requirements as the main 28 volt bus.

IRD-601 Instrument design shall be such that having both primary and redundant safe-hold/survival heater circuits enabled does not violate any thermal or power requirement.

Rationale:

If both safe-hold/survival circuits are enabled it does not mean that both circuits are drawing current. Since either circuit has to be able to meet the thermal requirements, if both circuits are drawing current, the instantaneous power drawn would exceed the allowed maximum by a factor of 2.

IRD-603 Safe-hold/survival power shall be used within the instrument only for resistive heaters (and associated thermal control device) which maintain the instrument at minimum turn-on temperature when the main power bus is disconnected from the instrument.

Rationale:

"Minimum turn-on" refers to the temperature at which the instrument can be sustained indefinitely without degradation in performance, once operational power has been restored and a turn-on sequence followed. The initial application of operational power by the spacecraft (turn-on) can be made at this 'minimum turn-on' temperature. Restoration of full operational status will involve a sequence of events following that initial turn-on, and may involve intermediate temperature constraints which must be observed.

IRD-605 The instrument contractor shall identify (for documentation in the ICD by the spacecraft contractor) if more than 2 circuits are required (1 primary and 1 redundant).

IRD-606 The instrument shall provide thermal control of the safe-hold/survival heaters which is single-fault tolerant against both excessive and insufficient application of heat.

IRD-1623 The instrument shall identify the extent of the safe-hold/survival heater thermal control redundancy, for documentation in the ICD by the spacecraft contractor.

Rationale:

The thermal control arrangement is intended to protect the spacecraft from excessive current drain by the instrument if the control fails ON, and to protect the instrument from becoming too cold if the control fails OFF. Whether parallel redundancy, series redundancy, or both is needed depends on the current drain, allowable instrument temperatures, and other factors.

IRD-608 Safe-hold/survival heater circuit impedance shall be documented in the ICD by the spacecraft contractor.

IRD-609 The safe-hold/survival heaters shall be functionally redundant.

IRD-610 Safe-hold/survival heater power buses shall be electrically isolated from each other, from other instrument thermal control, from chassis, and shall have independent power returns.

IRD-611 The spacecraft shall ensure that both the primary and redundant safe-hold/survival heater circuits are normally enabled on-orbit when an instrument is off.

Rationale:

Safe-hold/survival heaters may be turned off in the event of an Observatory emergency where the survival of the spacecraft is in jeopardy.

3.4.4.4.3 Safe Bus Operation

The spacecraft will turn on the safe bus during those periods where it is intended to be used for safety critical activities, such as operation of a calibration mechanism or gimbal deployment. The primary and redundant safe bus power may or may not be on at the same time, depending on spacecraft operations.

IRD-615 The instrument design shall not rely on presence of the Safe Bus at any time other than for initial activation of safety-critical items.

3.4.4.5 Grounds, Returns, and References

3.4.4.5.1 Grounding Responsibility

IRD-618 The spacecraft shall employ a single-point-ground configuration.

IRD-619 The spacecraft contractor shall document the observatory grounding scheme in the LDCM Observatory Electrical Requirements Document.

IRD-620 All grounding interfaces from the instrument components to the spacecraft shall be documented in the ICD by the spacecraft contractor.

3.4.4.5.2 External Ground Tie Point

IRD-622 The instrument contractor or provider shall identify an external chassis ground tie point to be used for external connections while the instrument is being moved, and documented in each instrument MID. This ground point may be the same point used as the connection point to the spacecraft common ground path.

3.4.4.5.3 Thermal Blanket Grounding

IRD-624 All thermal blanket layers shall be grounded.

3.4.4.6 Electrical Harnesses and Connectors

3.4.4.6.1 Electrical Harnesses

3.4.4.6.1.1 Harness Wiring Requirements

IRD-628 Power harnesses within the instrument and the spacecraft shall be appropriately sized to support the peak allocated power levels and spacecraft fusing.

IRD-629 Power and signal circuits shall utilize separate connectors.

IRD-630 Safe-bus power shall utilize dedicated connectors separate from those used for any other purpose.

3.4.4.6.1.2 Harnesses Provider

IRD-632 All flight harnessing used on the spacecraft to connect the spacecraft to the instrument interface bracket shall be provided by the spacecraft contractor using connectors provided by the instrument contractor.

IRD-633 Flight harnessing shall be designed as specified by the appropriate ICD.

IRD-634 Intra-instrument harnessing, exterior to the instrument housing and connecting different parts of a single-unit instrument, or different parts of a multiple-assembly instrument mounted on a single baseplate, shall be provided by the instrument contractor or provider.

3.4.4.6.1.3 Harness Documentation

IRD-636 Harnesses, connectors, ground straps, and associated service loops shall be documented in the respective ICDs (Instrument ICD by the instrument contractor or provider and spacecraft ICD by the spacecraft contractor), including all requirements for harness construction, pin-to-pin wiring, cable type, etc.

3.4.4.6.1.4 Harness Tie Points

IRD-638 The locations of harness tie points will be an agreement between the instrument contractor and the spacecraft contractor, and shall be documented in the ICD by the spacecraft contractor.

3.4.4.6.1.5 Harness Mass Accounting

IRD-640 The mass for instrument power and signal harnesses from the spacecraft power distribution electronics to the spacecraft/instrument interface bracket shall be accounted for as part of the spacecraft mass.

IRD-1443 The mass for instrument power and signal harnesses from the spacecraft/instrument interface bracket to the instrument shall be accounted for as part of the instrument mass.

3.4.4.6.2 Electrical Connectors

3.4.4.6.2.1 General Considerations

IRD-643 Primary and redundant connectors shall be differentiated by clearly marking all boxes and cables.

IRD-644 The instrument contractor or provider shall provide two sets of mated pairs of interface connectors for each instrument.

IRD-645 The instrument contractor or provider shall provide static-discharging connector covers, delivered in-place with the instrument.

IRD-646 The instrument interface mating connectors dimensions and locations shall be documented in the ICD by the spacecraft contractor.

IRD-647 For instrument connections to the spacecraft harness, there shall be a minimum 25.4 mm clearance around the outside of mated connectors so that there is no need for "blind mate/demates" or a need for removing adjacent instruments in order to mate or demate a harness connection.

Rationale:

Provision of clearance around the outside of connectors is the responsibility of the spacecraft contractor.

IRD-648 All spacecraft connectors for all instrument connections shall have recessed contacts (e.g. female) to minimize inadvertent contact when the instrument is not mated.

IRD-650 Captive covers shall be installed for all instrument connectors that are not mated to harnesses or flight plugs.

IRD-651 All connectors that are not used for flight or for EMI/EMC testing shall be covered with EMI tight covers.

3.4.4.6.2.2 Connector Location and Types

IRD-653 Connectors shall be located on the anti-cold-space side (sun side) of the instrument, except in those cases where local conflicts exist on the sun side, and that exception shall be documented in the ICD by the spacecraft contractor.

IRD-654 Connector locations, types, and orientations shall be documented in the respective ICDs (instrument ICD by the instrument contractor or provider and spacecraft ICD by the spacecraft contractor).

3.4.4.6.2.3 Keying

IRD-656 Connectors shall be different sizes, different types, different orientation, color coded or uniquely keyed (in order of preference) to the extent feasible in order to prevent improper connection.

3.4.4.6.2.4 Flight Plugs

IRD-658 Flight plugs requiring installation prior to launch shall be capable of being installed at the Observatory level.

IRD-659 Flight plugs and their locations shall be documented in the respective ICDs (instrument ICD by the instrument contractor or provider and spacecraft ICD by the spacecraft contractor).

3.4.4.6.2.5 Buffer Connectors and Connector Savers

IRD-661 Instrument buffer connectors and connector savers shall be utilized prior to spacecraft-level system tests.

Rationale:

The intention is to mitigate risk of bent pins or otherwise damaged flight connectors.

3.4.4.6.2.6 Test Connectors

IRD-664 Test point interface circuit and equipment failures shall not be capable of propagating failures into the instrument. This includes credible failures in GSE connected externally to the test point interface connectors.

IRD-665 Captive flight quality and flight capable test connector covers shall be installed whenever the test connector is not in use.

IRD-666 Test connectors and their locations shall be documented in the respective ICDs (instrument ICD by the instrument contractor or provider and spacecraft ICD by the spacecraft contractor).

3.4.4.6.3 Breakout Boxes

IRD-668 Test-tees, interrupt boxes, and breakout boxes for instrument-to-spacecraft interfaces shall be provided by spacecraft contractor.

3.4.5 Command and Data Handling

Unless specified otherwise, the requirements in this section apply to all Command and Data Handling (C&DH) interfaces.

3.4.5.1 Data Bus Requirements

3.4.5.1.1 Bus Functions

The primary means of Mission Data exchange between the OLI and TIRS instruments and the spacecraft are through the High Speed Science Data Bus (HSSDB). Commanding and low rate telemetry exchanges are handled through a 1553 interface. TSIS utilizes the 1553 for commanding, science data, and housekeeping telemetry.

IRD-697 The spacecraft and instruments shall interface across the High Speed Science Data Bus (HSSDB).

IRD-706 The Spacecraft shall receive the Mission Data (image data and image ancillary data) from Earth imaging instrument(s).

IRD-709 The Spacecraft shall receive the transfer of instrument diagnostic data from the instrument over the MIL-STD-1553 data bus.

IRD-1917 The Spacecraft shall send the predicted velocity vector in Earth Centered Inertial once per second over the MIL-STD-1553 data bus.

IRD-701 The Spacecraft shall provide the transfer of real-time commands to the instrument.

IRD-1444 All ground commands to the Science Instrument FSW shall first pass through the Spacecraft FSW.

IRD-702 The Spacecraft shall provide the transfer of stored commands to the instrument.

IRD-703 The Spacecraft shall provide the transfer of memory (tables and parameters) loads commands to the instrument.

IRD-704 The Spacecraft shall provide the transfer of time to the instrument

IRD-707 The Spacecraft shall receive the transfer of housekeeping and health and safety data from the instrument.

IRD-708 The Spacecraft shall receive the transfer of transition to safe mode indicator from the instrument.

IRD-710 The Spacecraft shall receive the transfer of memory dumps from the instrument.

IRD-711 The Spacecraft shall receive the transfer of safe-hold/survival mode temperatures (not part of the data bus) from the instrument.

IRD-1446 Spacecraft FSW shall provide the capability for the exchange of Keep Alive messages between the Spacecraft FSW and the Science Instrument FSW.

IRD-1447 Spacecraft FSW shall receive notification from the Science Instrument FSW of the Science Instrument state and of Science Instrument anomalies requiring Spacecraft FSW action.

3.4.5.2 Interface Characteristics

3.4.5.2.1 High Speed Serial Science Data Bus (HSSDB)

The HSSDB is defined as the set of interfaces from the OLI instrument and the TIRS instrument to the Spacecraft. Instrument data allocations are "not to exceed" rates.

IRD-715 The spacecraft shall receive Instrument Mission Data via the High Speed Science Data Bus (HSSDB).

IRD-1950 The spacecraft shall provide 64 HSSDB Low Voltage Differential Signaling (LVDS) signal lines to the instruments;

- OLI: 24 Primary and 24 Redundant (TBR)
- TIRS: 4 Primary and 4 Redundant
- Spares: 4 Primary and 4 Redundant

IRD-716 The details of the HSSDB shall be documented in each Instrument to Spacecraft ICD by the spacecraft contractor.

IRD-717 The HSSDB may consist of a single or multiple physical interfaces, and any necessary handshaking or flow control to manage the interface.

3.4.5.2.1.1 HSSDB Data Rate

IRD-720 The OLI instrument total uncompressed data rate average during an image interval shall be less than or equal to 265 Mbps.

IRD-1387 The TIRS instrument total uncompressed data rate average during an image interval shall be less than or equal to 26.2 Mbps.

Rationale:

Instrument data rates drive overall system data rates and solid state recorder size, and ultimately the capabilities required of the wideband communication system. It is incumbent on the instrument contractors to minimize the HSSDB data rate as much as possible consistent with delivering all data necessary to meet the mission requirements.

3.4.5.2.1.2 HSSDB Physical Layer

The physical layer of the HSSDB shall be ANSI/TIA/EIA-644-A compliant low-voltage differential signaling (LVDS).

3.4.5.2.1.3 HSSDB Data Format

IRD-725 The HSSDB data stream shall include the instrument data and information on data type and data timing (timestamp) as necessary to support file operations of the Spacecraft SSR.

3.4.5.2.2 MIL-STD-1553 Bus

IRD-742 The spacecraft contractor shall define the bus implementation characteristics in the LDCM Observatory 1553 Bus ICD.

IRD-1916 Instrument commands and low rate telemetry exchanges shall be performed over the MIL-STD-1553.

IRD-1919 The LDCM TSIS total data rate average shall be less than or equal to 8 kbps sent over the 1553 Bus.

IRD-743 Unspecified parameters shall not be assumed or assigned by the instrument contractor without concurrence from the spacecraft contractor, at which time they are to be documented in the LDCM Observatory 1553 Bus ICD by the spacecraft contractor.

3.4.5.2.3 Pulse Commands

IRD-745 Pulse commands from the spacecraft shall not be used for functions which could be accomplished by the instrument itself, or by command from the spacecraft via the data bus.

Rationale:

The primary means of commanding the instrument is through the command & data interface. If necessary, and as approved by the spacecraft contractor and documented in the ICD, selected commands may utilize pulse (relay driving) commands, having the characteristics given below.

IRD-747 Instrument discrete pulse commands shall have redundant interfaces per function, one primary, and one redundant, each controlled by one wire pair (command/return).

IRD-748 The pulse command characteristics shall be defined in the ICD by the spacecraft contractor.

3.4.5.2.4 Time of Day Pulse

IRD-750 The spacecraft shall provide a 1 Hz Time of Day pulse to indicate the point in time at which to apply the time code which was previously transmitted over the data bus.

IRD-751 The instrument shall utilize the rising edge of the Time of Day pulse, together with the time code data, in order to establish the time reference for instrument data.

IRD-752 The Time of Day pulse characteristics shall be defined in the ICD by the spacecraft contractor.

IRD-753 The spacecraft shall issue the Time of Day pulse rising edge (non-inverting side of differential interface) within 250 nanoseconds of each spacecraft 1-second time occurrence.

3.4.5.3 Instrument Commands and Data Load

IRD-757 The standard means of transmitting commands and data loads from the spacecraft to the instrument shall be via the 1553 data bus.

IRD-758 The spacecraft shall, through the MIL-STD-1553 bus, deliver the instrument command and data load to the specified instrument RT-receive address/sub-address by conducting BC-to-RT Transfers or RT-to-RT Transfers (from a spacecraft RT to an instrument RT).

IRD-759 The spacecraft shall provide discrete commands for instrument operational and safe-hold/survival heater power switching, fault recovery, and safe bus functions as necessary.

IRD-761 All commands to be transferred to the instrument via the point-to-point (discrete) command interfaces and the command and telemetry bus shall be documented in the ICD by the spacecraft contractor.

3.4.5.3.1 Commands

IRD-763 The instrument contractors or providers shall provide command information to the spacecraft contractor for inclusion in the LDCM Observatory 1553 Bus ICD.

IRD-764 Commands to instruments from the spacecraft shall be documented in the LDCM Observatory 1553 Bus ICD by the spacecraft contractor.

IRD-765 No single point failure shall prevent the instrument components from receiving commands.

3.4.5.4 Instrument Housekeeping Telemetry, Memory Dump, Monitoring

IRD-767 The instrument contractors shall provide instrument housekeeping telemetry information to the spacecraft contractor for inclusion in the LDCM Observatory 1553 Bus ICD.

IRD-768 Instrument housekeeping telemetry shall be documented in the LDCM Observatory 1553 Bus ICD by the spacecraft contractor.

IRD-769 No single point failure shall prevent spacecraft access to critical telemetry points.

3.4.5.4.1 Point-to-Point Telemetry

Point-to-point telemetry is intended to represent "static" information (for example: relay status associated with pulse commands where knowledge of the relay position is required even when the instrument is off) such that sampling rates in the seconds, or tens of seconds, is adequate.

IRD-772 All spacecraft-instrument point-to-point telemetry interfaces shall be documented in the ICD by the spacecraft contractor.

IRD-773 Instrument component point-to-point telemetry shall include redundant passive analog temperature measurement devices.

Rationale:

Redundancy may be accomplished by thermally overlapping regions for non-critical measurements. These analog lines are separate and in addition to any state of health (SOH) input being transmitted over the command and data interface and are intended to provide insight during periods when the instrument operational power is not present; therefore, excitation of the passive analog temperature measurement devices is provided by the spacecraft.

3.4.5.4.2 Command Verification via Telemetry

IRD-776 Receipt of individual commands via the Command & Data bus shall be verifiable via instrument housekeeping telemetry.

IRD-777 Receipt of individual Pulse commands shall be directly verifiable via Point-to-Point Telemetry or some other means.

3.4.5.4.3 Instrument Memory Dump

IRD-779 Instrument Memory Dump data shall be transferred to the spacecraft C&DH via the 1553 data bus as specified in the ICD.

3.4.5.4.4 Telemetry Monitor

IRD-781 Any requirement for the spacecraft to monitor selected telemetry points (including telemetry from the command and telemetry bus and point-to-point interfaces) and initiate action to the instrument based upon a pre-determined telemetry state shall be negotiated with the spacecraft contractor and documented in the ICD by the spacecraft contractor.

IRD-782 All instrument telemetry points to be monitored by the spacecraft, for spacecraft action, shall be documented in the ICD by the spacecraft contractor, along with the action to be taken and the algorithm for such action, as specified by the instrument contractor.

IRD-783 The Spacecraft Telemetry Monitor (TMON) function shall perform threshold checking on specific data items as described in the ICD.

IRD-784 The TMON function shall be capable of activating a stored command sequence when errors are detected (i.e. a defined threshold is exceeded).

IRD-785 The TMON data thresholds shall be defined in tables in the flight software.

IRD-786 The TMON tables shall be modifiable by the ground via a Memory Load operation.

IRD-787 The TMON function shall compare the collected data with the predefined limits defined in the tables.

IRD-788 Any payload telemetry parameter that requires monitoring by the spacecraft shall be placed in a TMON packet message.

IRD-789 The format description of TMON packets shall be defined in the ICD by the spacecraft contractor.

IRD-790 The instrument contractors shall provide to the spacecraft contractor the autonomous fault response algorithm for each TMON monitor point.

3.4.5.5 Command & Data Interface Test Packets

IRD-792 The OLI and TIRS instruments shall be capable of generating and transmitting, on command, a continuous sequence of packets containing a fixed data pattern over the HSSDB.

Rationale:

Test pattern for test or diagnostic purposes.

IRD-793 Instrument test packets shall have a unique APID.

IRD-794 Test Packet APIDs, patterns and lengths shall be documented in the ICD by the spacecraft contractor.

3.5 ENVIRONMENTAL CONDITIONS

This section specifies the environment characteristics in the presence of which the spacecraft and the instrument components must meet all other requirements.

3.5.1 Radiation Environment

IRD-798 The spacecraft and instruments shall be capable of meeting all performance requirements for the ionization and displacement damage levels produced by the natural radiation environments at the operational orbits for the mission design lifetime.

3.5.2 Meteoroid and Debris Environments

IRD-800 Spacecraft and Instrument materials that are directly exposed to free space, such as cables, propulsion lines, pressurized tanks, and sensor optics, shall be designed to remain operable within their performance specifications over the mission design lifetime in the meteoroid and space debris environments in the operational orbit.

3.5.3 Spacecraft Magnetic Fields

IRD-802 The spacecraft and instruments shall not exhibit any malfunction, degradation of performance or deviation from the specified indications beyond the tolerances indicated in their individual equipment specifications as a result of being exposed to DC magnetic levels not exceeding the natural Earth field at sea level.

3.5.4 Atomic Oxygen

IRD-804 The spacecraft and instruments shall meet performance requirements during exposure to atomic oxygen (AO) experienced over the mission lifetime in the environments in the operational orbit.

3.5.5 Spacecraft Charging from All Sources

IRD-806 The spacecraft and instruments shall operate without performance degradation due to the surface charging, bulk charging, and deep charging environment.

3.5.6 Launch Environment

The baseline LDCM launch vehicle is an Atlas 5, Model 401 with a 4 meter fairing.

IRD-809 The spacecraft and instruments shall be compatible with the launch environments as specified in the LDCM Launch Services Interface Requirements Document (LS-IRD), GSFC-427-08-01),and the LDCM Environmental Verification Requirements (LEVR), GSFC-427-03-05.

3.6 DESIGN AND CONSTRUCTION

3.6.1 Instrument Electrical Power Interface Design Requirements

IRD-812 The instruments shall have EMI input filters installed on the instrument side of the power interface.

IRD-813 The filters shall provide both common-mode and differential-mode filtering.

3.6.2 Instrument Mechanical Interface Design Requirements

3.6.2.1 Instrument Mechanisms

IRD-816 Instrument mechanisms which require restraint during launch shall be caged during launch without requiring power to maintain the caged condition.

IRD-817 Instrument mechanisms which require caging and/or uncaging during test shall be capable of being caged or uncaged by command and by manual actuation of accessible locking/unlocking devices.

IRD-818 Instrument mechanisms which require uncaging and/or caging on-orbit shall be capable of being caged and uncaged by command.

3.6.2.2 Uncompensated Momentum

This section defines the requirements and limits for instrument-induced disturbances that are transmitted to the spacecraft. These instrument limits apply to the uncompensated momentum and torques that the instrument may apply to the instrument to spacecraft interface.

IRD-820 Each instrument having movable components shall not exceed an uncompensated momentum contribution of +/- 0.5 N-m-sec (TBR) per axis.

IRD-821 The uncompensated momentum contribution of the instrument shall be documented in the instrument ICD, by the instrument contractor or provider.

3.6.2.3 Instrument Disturbance Allocations

IRD-823 Each instrument contractor shall provide early estimates of gimbaled masses, inertias, and center of gravity to the spacecraft contractor to permit sizing the control components to meet Observatory pointing and stability requirements.

Rationale:

Estimates are provided in each Instrument Interface Information Document.

3.6.2.3.1 Periodic Disturbance Torque Limits

IRD-825 The instrument contractor or provider shall provide, in electronic format, amplitude vs. time plots and spectral content plots of each uncompensated force and torque to the spacecraft contractor for analysis.

IRD-826 The magnitude of the periodic disturbance torque, including the torque resulting from linear forces reacting from the instrument to the spacecraft shall be in the acceptable range of Figure 3.17 for all frequencies.

IRD-827 The instrument ICD shall specify the predicted disturbance torque contributions to the spacecraft, if any.

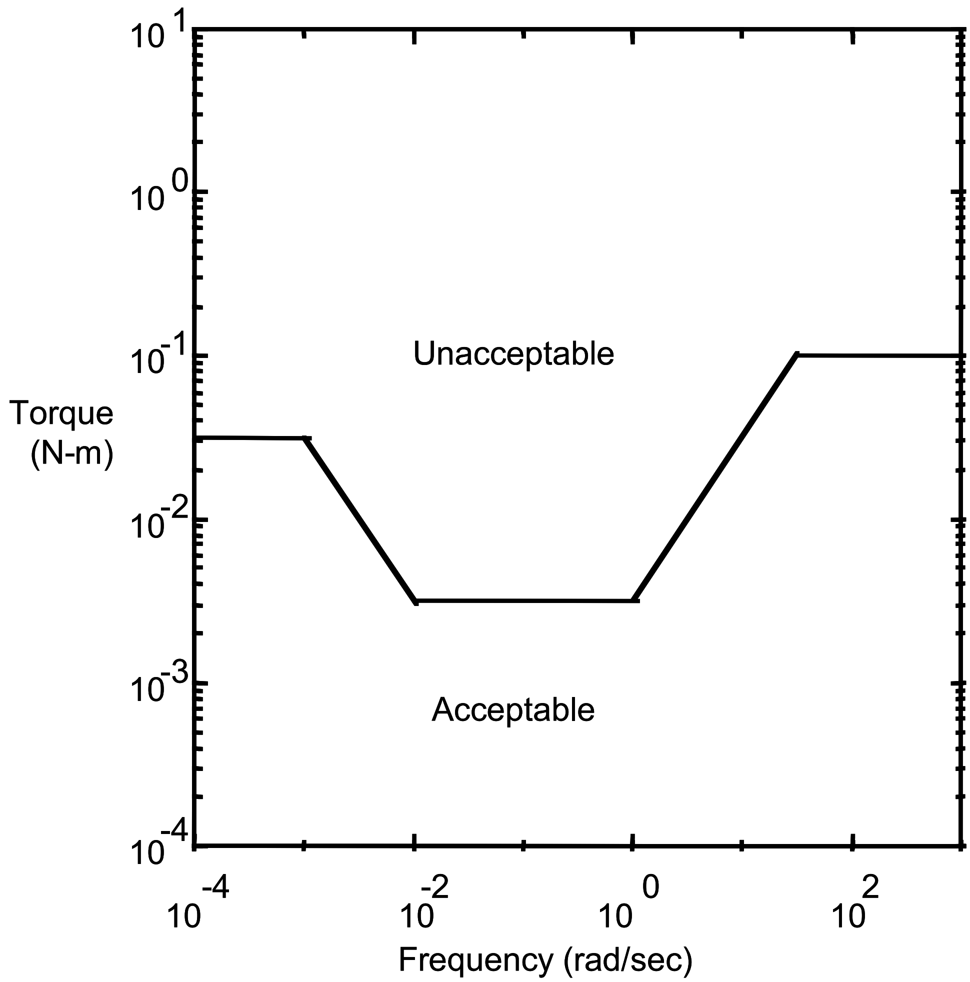


Figure 3-17. Allowed Transmitted Torque (TBR)

3.6.2.3.2 Constant Disturbance Torque Limits

IRD-848 Instrument-induced constant disturbances of the same polarity, separated by more than 200 seconds, shall not exceed the torque limit defined in Figure 3.18 if the duration of application is in excess of 10 seconds.

Rationale:

For constant torques of 400 seconds duration or more, the torque limit is maintained at the 400 second limit shown in Figure 3-18.

IRD-1023 For constant torques of 10 seconds duration or less, the limit shall be 0.04 N-m-s (TBR).

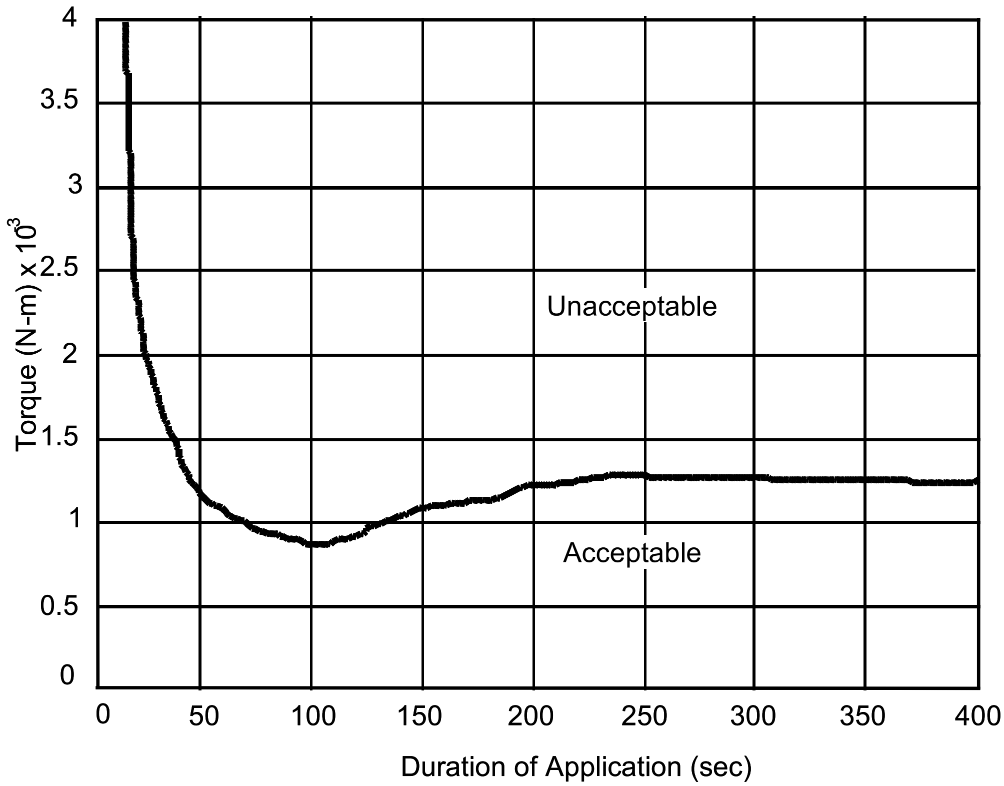


Figure 3-18. Constant Torque vs. Duration of Application (TBR)

3.6.2.3.3 Disturbance Torque Limits for Linear Forces

IRD-853 Uncompensated instrument disturbance forces shall be analyzed as acting through the appropriate moment arms to the spacecraft center of mass, and are subject to the torque limits previously defined.

IRD-854 The torques about the spacecraft CM resulting from instrument linear forces shall be documented in the ICD by the spacecraft contractor.

3.6.2.3.4 Spacecraft Non-Operational Deployment Disturbance

IRD-856 The on-orbit non-operational Spacecraft disturbances produced by the uncaging or deployment of any mechanism or device shall be less than 158 N-m (TBR) at the point of attachment.

3.6.2.3.5 Torque Profile Documentation

IRD-858 The instrument contractor or provider shall provide the typical instrument torque versus time profile to the spacecraft contractor for documentation in the ICD.

3.6.2.3.6 Thrust Direction Definition

IRD-860 The instrument contractor or provider shall provide to the spacecraft contractor the magnitude and direction of net thrust, timing of expulsion events, and expulsion material resulting from the expulsion of expendables by the instrument, for documentation in the ICD.

3.6.3 Access

3.6.4 General Access

IRD-866 The instrument contractor or provider shall provide to the spacecraft contractor access requirements for documentation in each instrument MID.

IRD-868 All items to be installed, removed, or replaced at the spacecraft level shall be accessible without disassembly of the unit.

IRD-869 Access requirements and clearances shall be mutually agreed-upon between the spacecraft contractor and the instrument contractor, and specified in the ICD by the spacecraft contractor.

3.6.5 Instrument-to-Spacecraft Mounting/Handling

IRD-872 Each instrument shall be capable of being mounted to the spacecraft with the spacecraft interface in the horizontal orientation.

IRD-874 Each separately-mountable instrument component shall be capable of being installed and removed without removal of other instruments or subsystems, and without demating or removal of harness (including coax) other than for the unit being removed.

IRD-875 Connector access for removal and reassembly of an instrument shall be accomplished without requiring removal of any equipment.

IRD-876 Installation/removal of any separately-mountable component shall not require rotation of the spacecraft during installation/removal.

IRD-878 The instrument contractor shall provide a list of items to be installed or removed prior to flight, for identification in the ICD by the spacecraft contractor.

3.6.6 Venting

IRD-880 Instrument contractors shall provide to the spacecraft contractor the location, size, path, venting forces and impulses, direction of net thrust, and operation time of vents in the instruments for inclusion in the ICD.

Rationale:

The instrument contractors venting design is coordinated with the spacecraft contractor, and if necessary tailored based upon the instrument mounting on the spacecraft.

IRD-881 The spacecraft contractor shall locate the instruments on the spacecraft such that the contamination products from the vents of one instrument cannot directly impinge on another instrument's contamination-sensitive surface nor directly enter another instrument's aperture.

3.6.7 Contamination

IRD-883 The instrument contractor or provider shall provide the contamination interface requirements to the spacecraft contractor for inclusion in the ICD by the spacecraft contractor.

Rationale:

This includes contamination sensitivity of the instrument, as well as identification and characterization of all sources of contamination that can be emitted from the instrument.

3.7 INTERFACE HARDWARE PROVIDERS

IRD-892 Interface hardware shall be provided by the organization shown below.

HARDWARE	PROVIDER
Standard mounting hardware (e.g., std. fasteners, shims)	Spacecraft
Special mounting hardware (instrument-unique)	Instrument
Instrument Mounts	Instrument
Optically aligned component drill template	Instrument
Non-optically aligned component drill template	Instrument
Instrument optical alignment target /cube and cover	Instrument
Instrument Holding and lifting fixtures	Instrument
Instrument GSE - special, electrical and mechanical	Instrument
Instrument GSE - general, electrical and mechanical	Spacecraft
Instrument Shipping containers	Instrument
Instrument to Spacecraft Flight connectors both sides of the electrical interface	Instrument

4.0 APPENDIX A _- DRC