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Lunar Reconnaissance Orbiter Project

Cosmic Ray Telescope for the Effects of Radiation to Spacecraft Thermal Interface Control Document

August 2, 2005

Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

CM FOREWORD

This document is a Lunar Reconnaissance Orbiter (LRO) 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 LRO 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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LUNAR RECONNAISSANCE ORBITER PROJECT

DOCUMENT CHANGE RECORD

Sheet: 1 of 1

REV LEVEL	DESCRIPTION OF CHANGE	APPROVED BY	DATE APPROVED
Rev -			

List of TBDs/TBRs

Item No.	Location	Summary	Ind./Org.	Due Date
1	Sections 1.5, 5.5.4	Provide title and document number for Optical Bench Assembly Drawing	L. Hartz/ GSFC	8/5/2005
2	Sections 1.5, 3.4	Provide drawing number for the Mechanical-Thermal Interface Drawing	???	???
3	Section 4.0	Update SC thermal design description. Currently describes design "E" concept.	B. Chang/ ESS	8/5/2005
4	Table 7-1	Provide Submodel and NODE numbers	H. Tan/ BU	8/5/2005
5	Table 7-2	Provide Node Numbers and Min./Max. Temp. Limites	???	???
6	Sections 7.5.1, 7.5.2, 7.6	Provide temperature limits	H. Tan/ BU	8/5/2005

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1.0 INTRODUCTION

The Lunar Reconnaissance Orbiter (LRO) is the first mission of the Robotic Lunar Exploration Program (RLEP). The LRO mission objective is to conduct investigations that will be specifically targeted to prepare for and support future human exploration of the Moon. This mission is currently scheduled to launch in October 2008 and is planned to take measurements of the Moon for at least one year.

1.1 GENERAL

This Thermal Interface Control Document (TICD) defines and controls the top level thermal interface between the LRO spacecraft and the Cosmic Ray Telescope for the Effects of Radiation (CRaTER) instrument necessary to manifest, build, test, and successfully fly the LRO mission.

1.2 PURPOSE

The purpose of this TICD is to ensure compatibility between the CRaTER instrument and the LRO spacecraft by:

a. Defining and controlling the interfaces between the instrument and the spacecraft; and

b. Defining top level constraints that shall be observed by the instrument and the LRO spacecraft. The top-level requirements are the general requirements that all subsystems must comply with to fly aboard the LRO mission.

1.3 APPROVAL

Approval of this TICD by the Configuration Control Board shall baseline the LRO spacecraft to instrument interfaces.

1.4 RESPONSIBILITY

The Goddard Space Flight Center (GSFC) has the final responsibility for the design of the thermal control system for the LRO spacecraft, its subsystems, and any requirements specifically assigned to LRO in this document.

Boston University (BU) has the final responsibility for the design of the Thermal Control System (TCS) for the CRaTER instrument, its subsystems, and any requirements specifically assigned to CRaTER in this document.

CRaTER shall be accompanied by all mechanical, electrical, and thermal ground support equipment (GSE) necessary to allow for full handling and thermal testing and will be provided by BU.

1.5 APPLICABLE DOCUMENTS

431-ICD-000008	Lunar Reconnaissance Orbiter Electrical Systems Specification
431-ICD-000084	Lunar Reconnaissance Orbiter Instrument Mechanical Interface Control Document
431-ICD-000085	Cosmic Ray Telescope for the Effects of Radiation to Spacecraft Mechanical Interface Control Document
431-ICD-000094	Cosmic Ray Telescope for the Effects of Radiation to Spacecraft Electrical Interface Control Document
431-PLAN-000110	Lunar Reconnaissance Orbiter Contamination Control Plan
431-RQMT-000092	Lunar Reconnaissance Orbiter Thermal Math Model Requirements
431-SPEC-000091	Lunar Reconnaissance Orbiter Thermal Systems Specification
GE2082828	CRaTER Mechanical-Thermal Interface Drawing
GXXXXXXXX	Optical Bench Assembly Drawing (TBD)
GEVS-STD-7000	General Environmental Verification Standards (GEVS) for Flight Programs and Projects

2.0 LRO REFERENCE COORDINATE SYSTEM

The LRO mechanical and thermal reference coordinate system is defined in the Lunar Reconnaissance Orbiter Mechanical Interface Control Document (431-ICD-000084). Unless otherwise noted, this document shall refer to the LRO reference coordinate system.

3.0 THERMAL INTERFACES

3.1 INTERFACE DEFINITIONS

The spacecraft-side interface is defined as the mounting surface on the spacecraft side of the interface.

The instrument-side interface is defined as the mounting surface on the CRaTER side of the interface.

3.2 INSTRUMENT REFERENCE LOCATIONS

Each Instrument Development Team (IDT) shall choose at least one reference location on each separate instrument assembly (e.g., electronics box, optical component, or detector assembly) at which temperature measurements can validate the thermal design. To support this validation, each location must be equipped with a spacecraft-monitored temperature sensor, be thermally separate from the spacecraft (at least to the degree that heat flow to/from the spacecraft can be quantified) and correspond to a node in the thermal model.

3.3 INSTRUMENT TEMPERATURE LIMITS

BU shall provide flight design, operational, survival, and qualification temperature limits associated with the above reference location(s). Refer to Section 2.1 of the Lunar Reconnaissance Orbiter Thermal Systems Specification (431-SPEC-000091) for a complete definition of these temperature limit types.

3.4 SPECIFICATION OF INSTRUMENT-SIDE TEMPERATURES

Each IDT shall, in this document:

a. Provide the reference location(s) on a Mechanical-Thermal Interface Drawing (**TBD**) (GXXXXXXXX) and a brief description of each location and its significance

b. Provide temperature limits associated with each reference location per Sections 3.2 and 3.3 of this document

c. Identify the node in the reduced thermal models delivered to GSFC corresponding to each reference location

3.5 ADDITIONAL THERMAL INFORMATION

For locations in the instrument that have significantly different temperature limits from the reference location, the IDT shall make each such location a node in its thermal model to be delivered to GSFC.

For locations in the instrument that have significantly different temperature limits from the reference location, the IDT shall provide the flight design limit for each node to the LRO Lead Thermal Engineer. No spacecraft-monitored temperature sensors are required for these additional locations; however, it may be advantageous to place instrument monitored temperature sensors at some or all of these locations.

4.0 SPACECRAFT THERMAL DESIGN CONCEPT (TBR GSFC:WSC)

The instruments and principal component/subsystems comprising LRO are depicted in Figure 4-1. The configuration shown reflects the design 'E' concept. LRO is divided into three (3) major segments plus the Solar Array Assembly (SAA) and High Gain Antenna (HGA). The three segments are the Instrument Module (IM), Avionics Module (AM) and Propulsion Module (PM).

The IM consists of the instrument deck and an optical bench (OB). The instruments are mounted to the OB along with the IRU. The OB is a 5.08 centimeters (cm) (2.0 inch [in.]) thick panel with aluminum honeycomb core sandwiched between two 0.1016 cm (0.040 in.) thick K13C face sheets. The –Z side of the OB serves as a radiating surface. The +Z side of the OB is covered with multi-layered insulation (MLI) having 15-layers. The outermost layer of the MLI will be 3-mil Kapton.

The AM is an eight-sided structure consisting of panels mounted to a skeletal frame. Each panel is 1.27 cm (0.5 in.) thick with aluminum honeycomb core sandwiched between two 0.1016 cm (0.040 in.) thick K13C face sheets. The AM houses the Battery, Command and Data Handling (C&DH) box, Propulsion and Deployable Electronics (PDE) box, Power System Electronics (PSE) box, S-Band Transponder and four Reaction Wheel Assemblies (RWA). The RWAs are mounted on the bottom deck while the remaining avionics boxes are mounted on the inboard face of some of the panels. The outboard faces of these panels serve as radiating surfaces to dissipate the heat rejected by the avionics boxes. The remaining panels are covered with MLI.

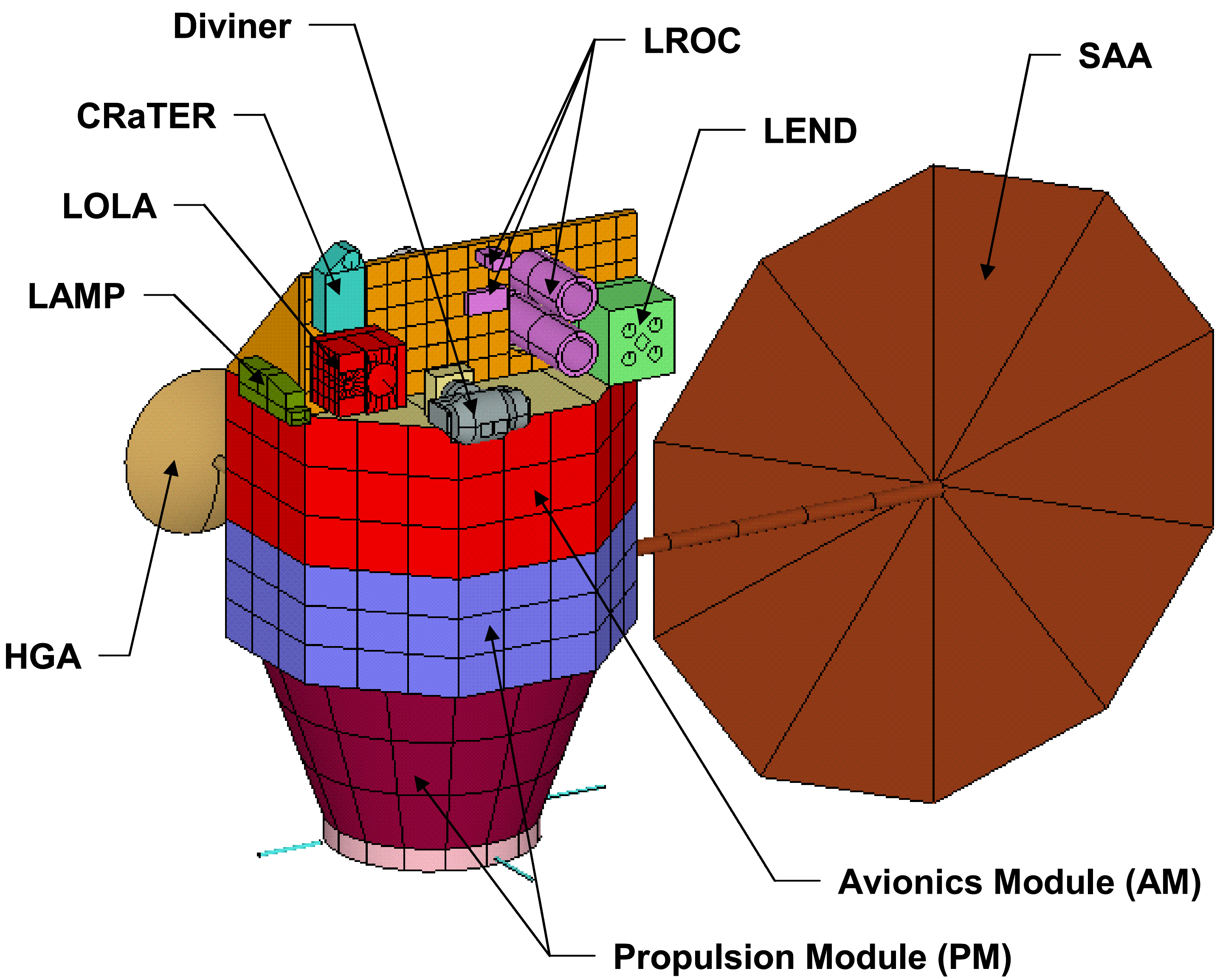

Figure 4-1. LRO Orbiter (Design 'E')

5.0 CRATER THERMAL DESIGN CONCEPT

CRaTER is conductively coupled to the spacecraft through the footprint of its six mounting feet. All exterior surfaces of the instrument excluding the scope apertures are insulated using 15-layered MLI blanket with a 3-mil Kapton outer layer. The scope apertures are covered with a single layer of 3-mil black Kapton. Optical properties of these surfaces are defined in Table 2-5 of the Lunar Reconnaissance Orbiter Thermal Math Model Requirements (431-RQMT-000092).

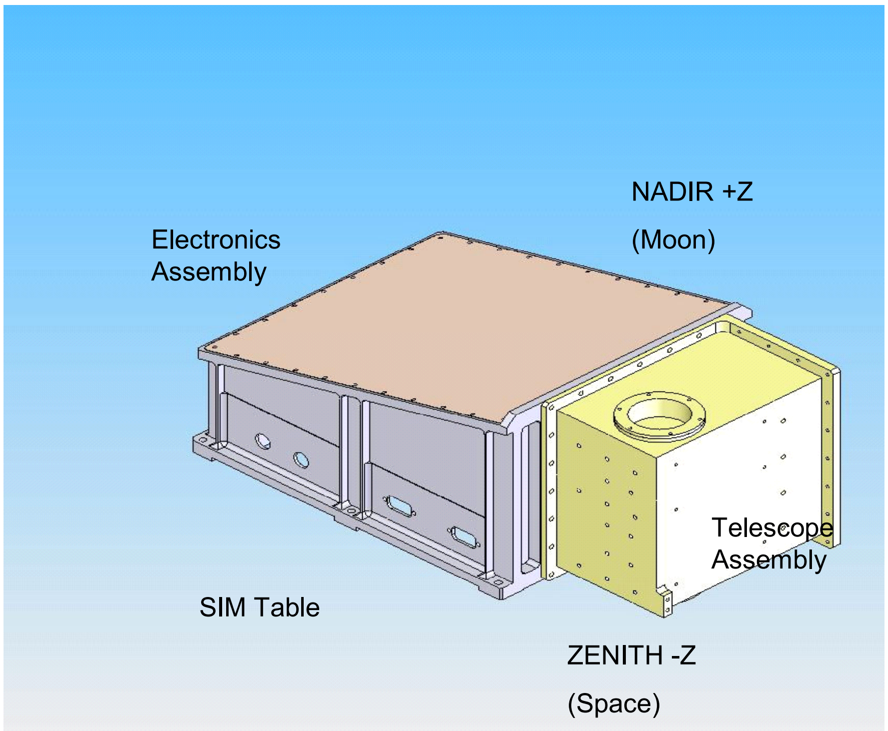

Figure 5-1. CRaTER Instrument

5.1 THERMAL COUPLING

5.1.1 CRaTER-to-Spacecraft Conductive Coupling

The spacecraft shall provide a conductive interface under the footprint of the CRaTER mounting feet.

Cho-Therm shall be placed between the CRaTER mounting feet and the spacecraft to enhance the conductive coupling.

5.1.2 CRaTER-to-Spacecraft Radiative Coupling

The spacecraft OB in the vicinity of CRaTER shall be covered by MLI. The outer layer of the MLI shall be 3-mil Kapton with an emittance > 0.76.

The spacecraft OB directly underneath CRaTER's footprint shall be bare K13C composite facesheet. The surface finish of the facesheet will have an emittance > 0.67.

5.2 INTERNAL CONTROLS

CRaTER has no internal heaters.

5.3 INTERNAL POWER DISSIPATIONS

CRaTER's power dissipation shall be in the range of 4.0 to 8.75 Watts and is constant throughout the orbit.

5.4 THERMAL CONTROL COATINGS

The mounting panel directly facing the OB shall be conversion coated aluminum. The surface finish of the mounting panel will have an emittance > 0.62.

5.5 THERMAL BLANKETS

BU shall provide and install all MLI that will cover the CRaTER instrument. The outermost layer of MLI viewing the spacecraft and neighboring instruments/components shall be 3-mil Kapton. Blanket details are specified in the CRaTER Mechanical-Thermal Interface Drawing (GE2082828).

5.5.1 Venting Requirements

Blankets shall be adequately vented in accordance with the Lunar Reconnaissance Orbiter Thermal Systems Specification (431-SPEC-000091).

Blanket venting details for the CRaTER instrument are provided in the CRaTER Mechanical-Thermal Interface Drawing (GE2082828).

5.5.2 Grounding Requirements

Blankets shall be adequately grounded in accordance with Lunar Reconnaissance Orbiter Electrical Systems Specification (431-ICD-00008).

Blanket grounding details for the CRaTER instrument are provided in the CRaTER Mechanical-Thermal Interface Drawing (GE2082828).

5.5.3 Cleanliness Requirements

Blankets shall be baked-out and meet cleanliness requirements in accordance with the Lunar Reconnaissance Orbiter Contamination Control Plan (431-PLAN-000110).

5.5.4 Blanket Interface with Spacecraft

Refer to the Optical Bench Assembly Drawing (Drawing # -TBD GXXXXXXX) for details regarding blanket interface between the spacecraft and the CRaTER.

6.0 INTERFACE TEMPERATURE REQUIREMENTS

6.1 TEMPERATURE RANGE REQUIREMENTS

The spacecraft has two thermal modes of operation, the operational mode and survival mode. The spacecraft TCS shall maintain the temperature on the spacecraft-side of the interface within the temperature ranges specified in Section 2.3 of the Lunar Reconnaissance Orbiter Thermal Systems Specification (431-SPEC-000091).

BU is responsible for meeting all performance requirements for the CRaTER instrument under the specified temperature range during all mission modes.

6.2 TEMPERATURE RATE-OF-CHANGE REQUIREMENTS

CRaTER has no temperature rate-of-change requirements.

6.3 TEMPERATURE GRADIENT REQUIREMENTS

CRaTER has no temperature gradient requirements.

7.0 TEMPERATURE MONITORING

7.1 CRATER REFERENCE LOCATIONS

The spacecraft shall allocate two spacecraft-monitored temperature sensors to the CRaTER instrument to be located on the instrument-side of the interface at their discretion. GSFC is responsible for providing the temperature sensors. The type of sensor used is specified in the Lunar Reconnaissance Orbiter Thermal Systems Specification (431-SPEC-000091).

A description of sensor locations along with their representative node in the thermal model is provided in Table 7-1. Temperature limits for these locations are provided in Section 7-5 of this document. Refer to the CRaTER Mechanical-Thermal Interface Drawing (GE2082828) for exact locations.

Table 7-1. CRaTER Reference Locations

#	DESCRIPTION	INT. / EXT.	SUBMODEL	NODE #
1	Telescope Wall	External	{TBS BU}	{TBS BU}
2	Digital PC Board	Internal	{TBS BU}	{TBS BU}

7.2 EXTERNALLY MOUNTED SPACECRAFT TEMPERATURE SENSORS

GSFC is responsible for installing the externally mounted spacecraft-monitored temperature sensor located at the Telescope Wall specified in the CRaTER Mechanical-Thermal Interface Drawing (GE2082828).

7.3 INTERNALLY MOUNTED SPACECRAFT TEMPERATURE SENSORS

BU is responsible for installing the internally mounted spacecraft-monitored temperature sensor located at the Digital PC Board specified in the CRaTER Mechanical-Thermal Interface Drawing (GE2082828).

7.4 INSTRUMENT MONITORED TEMPERATURE SENSORS

BU is responsible for providing and installing all temperature sensors that will be monitored by the instrument. The locations of these sensors are specified in the CRaTER Mechanical-Thermal Interface Drawing (GE2082828).

7.5 TEMPERATURE LIMITS

During all mission operational modes when the instrument is powered "ON", GSFC shall be responsible for maintaining the instrument within its operational temperature limits via the spacecraft TCS.

During all mission safe-hold modes when the instrument is powered "OFF", GSFC shall be responsible for maintaining the instrument within its survival temperature limits via the spacecraft TCS. CRaTER shall survive without damage or permanent performance degradation if powered "ON" anywhere within the survival temperature range.

A list of operational and survival temperature limits, along with flight design and qualification limits, is provided in Table 7-2.

Table 7-2. CRaTER Reference Location Temperature Limits

#	DESCRIPTION	NODE#	MIN/MAX TEMP. LIMITS (°C)			
			OPER.	SURV.	DESIGN	QUAL.
1	Telescope Wall	{TBS}	-20 to 30	-40 to 50	-25 to 35	-35 to 45
2	Digital PC Board	{TBS}	{TBS}	{TBS}	{TBS}	{TBS}

8.0 HEATERS

8.1 GENERAL REQUIREMENTS

Sizing of operational and survival heater capacity shall be based on 70% duty cycle (1/0.7=1.43 or 43% margin) at 24 Volts (V) bus voltage and cold case thermal conditions. Heater elements must be capable of operating over the voltage range of 28 ± 7V.

CRaTER shall provide space for mounting heaters, thermostats and temperature sensors.

Watt densities of the operational and survival heaters shall be appropriate for the type of heater and bonding method. Watt densities (at the maximum voltage) above 0.16 W/cm^2 (1.0 W/in^2) shall be discussed with the GSFC LRO Lead Thermal Engineer and may require (if a Kapton heater) bonding with Stycast 2850FT and aluminum over-taping up to 1.24 W/cm^2 (8.0 W/in^2).

8.2 OPERATIONAL HEATERS

GSFC shall provide any operational heaters, cabling and thermostats that are necessary. Any such heaters and associated hardware may be mounted either on the spacecraft, the CRaTER, or both. The placement of heaters shall be negotiated between GSFC and BU. GSFC shall install and the spacecraft shall control any such operational heaters, as needed, to maintain the temperatures on the spacecraft-side of the mounting interface within the operational temperature range specified in Section 6.1 of this document.

8.3 SURVIVAL HEATERS

GSFC shall provide any survival heaters, cabling and thermostats that are necessary. CRaTER's survival heaters and thermostats shall be located internal to the instrument housing. BU shall install and the spacecraft shall control any such survival heaters, as needed, to maintain the temperatures on the spacecraft-side of the mounting interface within the survival temperature range specified in Section 6.1 of this document.

8.4 DECONTAMINATION HEATERS

CRaTER has no decontamination heaters.

9.0 THERMAL MODEL REQUIREMENTS

9.1 GENERAL REQUIREMENTS

Each IDT shall deliver reduced thermal models and temperature predictions for relevant mission modes to GSFC. These models will be integrated with the spacecraft model that is used to generate flight predicted temperatures for various mission phases.

GSFC shall deliver either reduced thermal models of the Orbiter or environmental heating and spacecraft backload information to each IDT. Reduced thermal models allow each IDT to substitute their detailed model for the reduced representation of the instrument and perform any analyses deemed necessary. Environmental heating and spacecraft backload information will be based on the worst hot/cold operational and safe-hold cases for the spacecraft. Each IDT should bear in mind that the worst hot/cold case for the spacecraft may not necessarily be the worst hot/cold case for their instrument.

9.2 ENVIRONMENTAL CONSTANTS

Each IDT shall utilize the environmental constants specified in the Lunar Reconnaissance Orbiter Thermal Systems Specification (431-SPEC-000091).

9.3 THERMAL MODEL FORMATS

Each IDT shall deliver their geometry and thermal math models in the format specified in the Lunar Reconnaissance Orbiter Thermal Math Model Requirements (431-RQMT-000092). Said document provides specific requirements for model formats, naming conventions, etc. to facilitate integration of instrument models with the spacecraft model and shall be strictly adhered to.

9.4 INSTRUMENT REDUCED THERMAL MODEL REQUIREMENTS

The delivered thermal models shall be a reduced version of the detailed thermal models. The reduced geometry math model (RGMM) and reduced thermal math model (RTMM) shall include an adequate level of detail to predict, under worst case hot and cold conditions, all critical temperatures, including those that drive operational and survival temperature limits and heater power where applicable. Worst case conditions will include variations in season, orbit selection, orbital time, and environmental flux parameters (seasonal and spatial) and a rational combination of the effects of design tolerances, fabrication uncertainties, and degradation due to aging.

The RGMM and RTMM shall be correlated to the detailed models within ±2°C for critical nodes and components and shall include a representative node(s) at the reference location(s).

BU shall deliver an RGMM having no more than 50 surfaces and an RTMM having no more than 75 thermal nodes.

9.5 THERMAL MODEL DOCUMENTATION

The RGMMs and RTMMs delivered to GSFC shall be accompanied by appropriate model documentation as specified in the Lunar Reconnaissance Orbiter Thermal Math Model Requirements (431-RQMT-000092).

9.6 ORBITER DELIVERABLES

GSFC shall deliver either a set of reduced geometry and thermal models of the Orbiter or environmental heating and spacecraft backload information to each IDT.

9.6.1 Reduced Orbiter Thermal Models

For those vendors utilizing the Thermal Synthesizer System (TSS) and Systems Improved Numerical Differencing Analyzer (SINDA) software tools, GSFC shall provide an RGMM and RTMM of the complete Orbiter. Each vendor shall delete the representation of their instrument/component and replace it with their own detailed versions of the same. The models may then be used to perform any thermal analyses deemed necessary by the vendor.

The RGMM and RTMM shall be accompanied by model documentation as specified in the Lunar Reconnaissance Orbiter Thermal Math Model Requirements (431-RQMT-000092).

9.6.2 Environmental Heating and Spacecraft Backload Information

For those vendors utilizing thermal software tools other than TSS and SINDA, GSFC shall provide environmental and spacecraft backload information. Backload information will be mapped onto the external surfaces/nodes of the reduced thermal models that were provided to GSFC. In the absence of delivered models, backload information will be mapped onto reduced models developed by GSFC based on information that was available.

Backload information will be based on Orbiter hot, cold, and survival cases only. Note that the Orbiter hot and cold cases may not necessarily be the hot and cold cases for your particular instrument.

Backload information will be provided for each surface/node on a per unit area basis. It will be the responsibility of each vendor to map the backload data onto their detailed models.

10.0 THERMAL VACUUM TEST CONSIDERATIONS

The purpose of this section is to encourage vendors to anticipate, as much as possible, any special requirements and/or needs that may arise during Orbiter Thermal Vacuum (TVAC) testing. These may include, but not necessarily limited to, such items as test heaters or internal test temperature sensors as described below.

10.1 HIGH-VOLTAGE POWER SUPPLIES

CRaTER has no high voltage power supplies.

10.2 TEST HEATERS

During Orbiter TVAC testing, the test configuration of the Orbiter in the vicinity of each instrument may not be flight like due to placement of heater panels and cold plates to facilitate testing that will obviously not be present during flight. The primary objective during Orbiter TVAC will be to thermally test the LRO spacecraft. Consequently, test conditions may dictate that the effective sink temperature for some instruments may be colder than during the mission. Each IDT shall anticipate, to the extent possible, such possibilities and provide test heaters to keep the instrument within survival limits.

In such cases, the IDTs shall be responsible for providing their own test heaters, cabling and means of control. Any such heaters and associated hardware need not be flight qualified and shall be mounted on the instrument, not the spacecraft. The IDTs shall install and control any such test heaters, as needed, to maintain the safety of the instrument during TVAC.

Heater leads should be properly labeled and be of sufficient length to allow connection to test chamber heater harnesses.

10.3 TEST SENSORS

Where there is a desire to monitor temperatures of internal components during TVAC, each IDT shall deliver their instruments with the temperature sensor already installed. Temperature sensors used only during testing need not be flight qualified.

Temperature sensor leads should be properly labeled and be of sufficient length to allow connection to test chamber wire harnesses.

10.4 GREEN TAG ITEMS

Green tag items are those that must be installed prior to flight or environmental testing.

CRaTER has no green tag items.

10.5 RED TAG ITEMS

Red tag items are those that must be removed prior to flight or environmental testing.

CRaTER has no red tag items.

APPENDIX A. ABBREVIATIONS AND ACRONYMS

Abbreviation/ Acronym	DEFINITION
AM	Avionics Module
BU	Boston University
C&DH	Command and Data Handling
CCB	Configuration Control Board
CCR	Configuration Change Request
CM	Configuration Management
CMO	CM Office
CRaTER	Cosmic Ray Telescope for the Effects of Radiation
°C	Degrees Centigrade
ESS	Edge Space Systems, Inc.
GEVS	General Environmental Verification Standards
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HGA	High Gain Antenna
ICD	Interface Control Document
IDT	Instrument Development Team
IM	Instrument Module
in.	inch
LAMP	Lyman-Alpha Mapping Project
LEND	Lunar Exploration Neutron Detector
LOLA	Lunar Orbiter Laser Altimeter
LROC	Lunar Reconnaissance Orbiter Camera
LRO	Lunar Reconnaissance Orbiter
Max.	Maximum
Min.	Minimum
MLI	Multi-Layer Insulation
NASA	National Aeronautics and Space Administration
OPER.	Operation
OB	Optical Bench
PC	???
PDE	Propulsion and Deployables Electronics
PSE	Power Systems Electronics
PM	Propulsion Module
QUAL.	Qualification???
RGMM	Reduced Geometric Math Model
RLEP	Robotic Lunar Exploration Program
RQMT	Requirement

Abbreviation/ Acronym	DEFINITION
RTMM	Reduced Thermal Math Model
RWA	Reaction Wheel Assembly
SAA	Solar Array Assembly
SC	Spacecraft
SINDA	Systems Improved Numerical Differencing Analyzer
SPEC	Specification
STD	Standard
SURV.	Survival
TBD	To Be Determined
TBR	To Be Reviewed
TBS	To Be Supplied
TCS	Thermal Control System
TICD	Thermal Interface Control Document
TSS	Thermal Synthesizer System
TVAC	Thermal Vacuum
V	Volts
W/cm^2	Watts per square centimeter
W/in^2	Watts per square inch
WSC	White Sands Complex