

Lunar Reconnaissance Orbiter Project

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

LRO GSFC CMO

December 10, 2007

RELEASED



**National Aeronautics and
Space Administration**

**Goddard Space Flight Center
Greenbelt, Maryland**

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LUNAR RECONNAISSANCE ORBITER PROJECT**CHANGE HISTORY LOG**

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1.0 INTRODUCTION

The Lunar Reconnaissance Orbiter (LRO) is the first mission of the Lunar Precursor and Robotic Program (LPRP). 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 RESPONSIBILITY

The Goddard Space Flight Center (GSFC) has the final responsibility for the design of the Thermal Control System (TCS) 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 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.

1.4 APPLICABLE DOCUMENTS

| | |
|-----------------|---|
| 431-ICD-000085 | Cosmic Ray Telescope for Effects of Radiation to Spacecraft Mechanical Interface Control Document |
| 431-PLAN-000110 | Lunar Reconnaissance Orbiter Contamination Control Plan |
| 431-RQMT-000092 | Lunar Reconnaissance Orbiter Thermal Math Model Requirements |
| 431-SPEC-000008 | Lunar Reconnaissance Orbiter Electrical Systems Specification |
| 431-SPEC-000091 | Lunar Reconnaissance Orbiter Thermal Systems Specification |
| 32-06005.01 | Cosmic Ray Telescope for the Effects of Radiation Thermal-Vacuum Test Procedure |
| 32-02003.02 | Cosmic Ray Telescope for the Effects of Radiation Mechanical-Thermal Interface Drawing |

1.5 DEFINITION

In this document, a requirement is identified by “shall,” a good practice by “should,” permission by “may” or “can,” expectation by “will,” and descriptive material by “is.”

2.0 LRO REFERENCE COORDINATE SYSTEM

The LRO mechanical and thermal reference coordinate system is defined in the Cosmic Ray Telescope for Effects of Radiation to Spacecraft Mechanical Interface Control Document (431-ICD-000085). 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 plus any required thermally conductive materials.

3.2 INSTRUMENT REFERENCE LOCATIONS

BU shall choose at least one reference location on the CRaTER instrument where temperature measurements can validate the design and monitor the health and safety of the instrument. 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

BU shall, in this document:

- a. Provide the reference location(s) 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 the 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, BU 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, BU 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 CRATER THERMAL DESIGN CONCEPT

CRaTER is conductively coupled to the spacecraft through the footprint of its six (6) mounting feet. All exterior surfaces of the instrument excluding the scope apertures are insulated using 15-layered multi-layer insulation (MLI) blanket with a Germanium Black Kapton outer layer. The scope apertures are covered with a single layer of Kapton. Optical properties of these surfaces are defined in the Lunar Reconnaissance Orbiter Thermal Systems Specification (431-SPEC-000091).

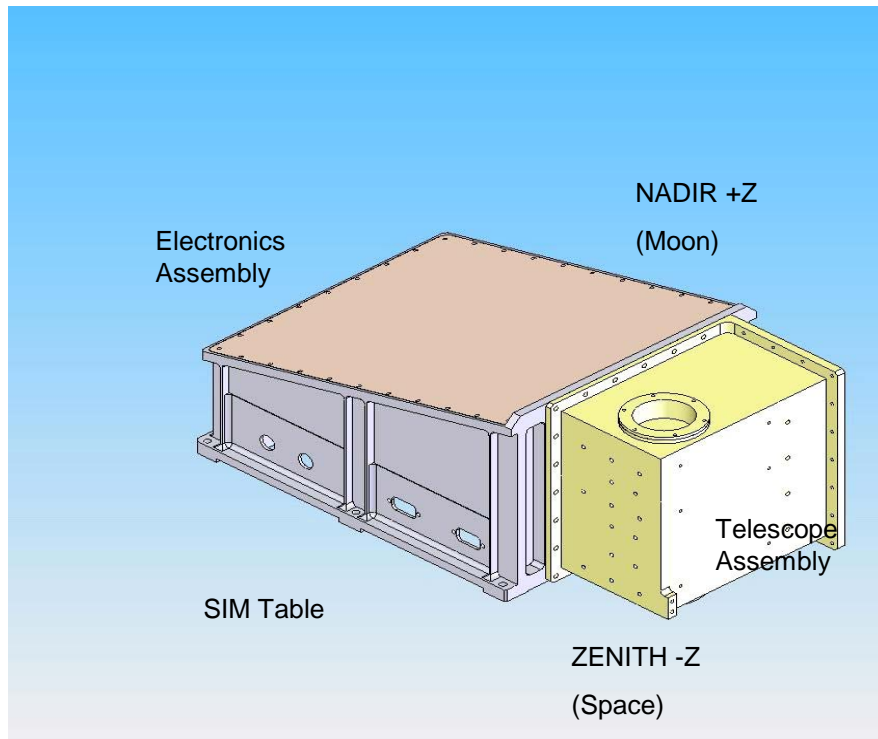


Figure 4-1. CRaTER Instrument

4.1 THERMAL COUPLING

4.1.1 CRaTER-To-Spacecraft Conductive Coupling

The LRO spacecraft to CRaTER instrument interface will be a bare aluminum to aluminum interface. The maximum heat flow across the CRaTER/Spacecraft interface shall be no greater than 9 Watts.

4.1.2 CRaTER-To-Spacecraft Radioactive Coupling

The spacecraft in the vicinity of CRaTER shall be covered by MLI. The outer layer of the MLI shall be Germanium Black Kapton with an emittance as specified in the Lunar Reconnaissance Orbiter Thermal Systems Specification (431-SPEC-000091).

The spacecraft directly underneath CRaTER's footprint shall be aluminum. The surface finish of the facesheet will have an emittance as specified in the Lunar Reconnaissance Orbiter Thermal Systems Specification (431-SPEC-000091).

4.2 INTERNAL CONTROLS

CRaTER has no operational heaters.

4.3 INTERNAL POWER DISSIPATIONS

CRaTER's internal thermal power dissipation is listed in the Lunar Reconnaissance Orbiter Thermal Systems Specification (431-SPEC-000091).

4.4 THERMAL CONTROL COATINGS

CRaTER's mounting panel directly facing the spacecraft shall be conversion coated aluminum. The surface finish of the mounting panel will have an emittance as specified in the Lunar Reconnaissance Orbiter Thermal Systems Specification (431-SPEC-000091).

4.5 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 Germanium Black Kapton. The CRaTER thermal blanket is being built by the GSFC blanket shop.

4.5.1 Venting Requirements

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

4.5.2 Grounding Requirements

The CRaTER instrument MLI shall comply with the grounding requirements in Section 3.2 of the Lunar Reconnaissance Orbiter Electrical Systems Specification (431-SPEC-000008).

4.5.3 Cleanliness Requirements

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

4.5.4 Blanket Interface with Spacecraft

The CRaTER thermal blanket is being built by the GSFC blanket shop. The CRaTER blanket interface with the spacecraft will be determined by the GSFC blanket shop.

5.0 INTERFACE TEMPERATURE REQUIREMENTS

5.1 TEMPERATURE RANGE REQUIREMENTS

The spacecraft has two (2) thermal modes of operation, the operational mode and survival mode. The spacecraft TCS shall maintain the temperature on the spacecraft-side of the interface to -30 to +25 C in normal operation, and to -40 to +35 C under survival conditions. CRaTER will be qualified to operate from -40 to +35C.

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

5.2 TEMPERATURE RATE-OF-CHANGE REQUIREMENTS

CRaTER has no temperature rate-of-change requirements.

5.3 TEMPERATURE GRADIENT REQUIREMENTS

CRaTER has no temperature gradient requirements.

6.0 TEMPERATURE MONITORING

6.1 CRATER REFERENCE LOCATIONS

The spacecraft shall allocate one spacecraft-monitored temperature sensor to the CRaTER instrument to be located on the instrument-side of the interface at BU’s 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 the sensor location along with their representative node in the thermal model is provided in Table 6-1. Temperature limits for this location are provided in Section 6-5 of this document. Figure 6-1 shows the location of the temperature sensor.

Table 6-1. CRaTER Reference Locations

| # | DESCRIPTION | INT. / EXT. | NODE # |
|---|----------------|-------------|----------|
| 1 | Telescope Wall | Internal | CR_XMAX7 |

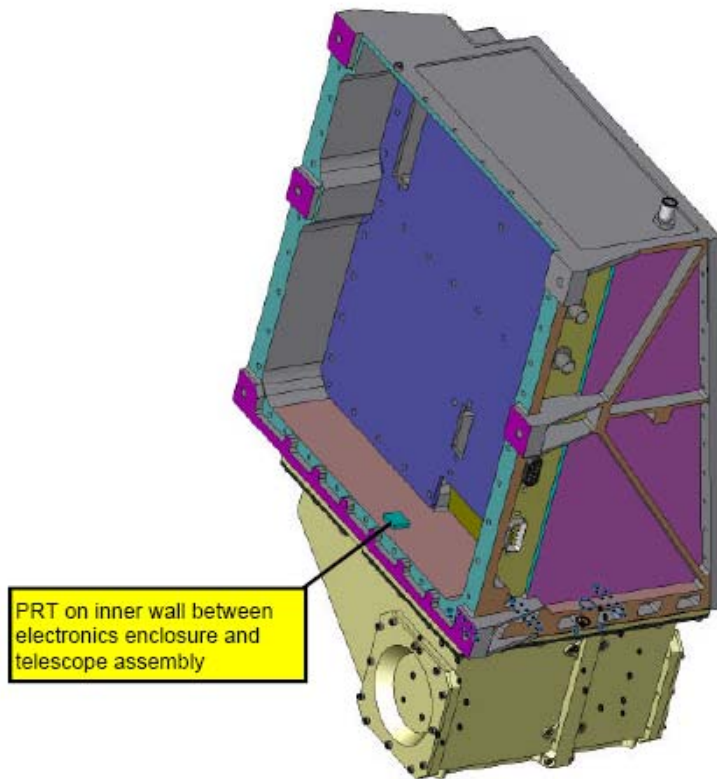


Figure 6-2: CRaTER Reference Temperature Location

6.2 EXTERNALLY MOUNTED SPACECRAFT TEMPERATURE SENSORS

CRaTER will not have any externally mounted temperature sensors.

6.3 INTERNALLY MOUNTED SPACECRAFT TEMPERATURE SENSORS

BU is responsible for installing the internally mounted spacecraft-monitored temperature sensor located at the telescope wall.

6.4 INSTRUMENT MONITORED TEMPERATURE SENSORS

CRaTER has five instrument monitored temperature sensors. The locations and temperature limits for these sensors are shown in the CRaTER Thermal-Vacuum Test Procedure (32-06005.01).

6.5 TEMPERATURE LIMITS

During all mission operational modes when the instrument is powered “ON” and the spacecraft is maintaining the CRaTER instrument interface temperature within the operational temperature limits described in section 5.1, the CRaTER instrument reference temperature shall stay within the operational temperature limits shown in Table 6-3.

During all mission modes when the instrument is powered “OFF” and the spacecraft is maintaining the CRaTER instrument interface temperature within the survival temperature limits described in section 5.1, the CRaTER instrument reference temperature shall stay within the survival temperature limits shown in Table 6-3. CRaTER shall survive without damage or permanent performance degradation if powered “ON” anywhere within the survival temperature range.

During the qualification testing of the CRaTER instrument, the instrument reference temperature shall remain within the qualification limits shown in Table 6-3.

Table 6-3. CRaTER Reference Location Temperature Limits

| # | DESCRIPTION | NODE# | MIN/MAX TEMP. LIMITS (°C) | | |
|---|----------------|----------|---------------------------|-----------|-----------|
| | | | OPER. | SURV. | QUAL. |
| 1 | Telescope Wall | CR_XMAX7 | -30 to 30 | -40 to 50 | -40 to 40 |

7.0 HEATERS

7.1 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 27 Volts (V) bus voltage and cold case thermal conditions. Heater elements must be capable of operating over the voltage range of $28 \pm 7V$.

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 Watts per centimeter squared (W/cm^2) (1.0 Watts per inch squared [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 $1.24 W/cm^2$ ($8.0 W/in^2$).

7.2 OPERATIONAL HEATERS

GSFC shall provide any operational heaters, cabling and thermostats that are necessary. Any such heaters and associated hardware may be mounted on the spacecraft, the CRaTER instrument, or both. The placement of heaters shall be negotiated between GSFC and BU and documented in the CRaTER Mechanical-Thermal Interface Drawing (32-02003.02). GSFC shall install and the spacecraft shall control any such operational heaters, as needed, to maintain the temperatures of the instrument to within the operational temperature range specified in Table 6-2 of this document.

7.3 SURVIVAL HEATERS

GSFC shall provide any survival heaters, cabling and thermostats that are necessary. CRaTER's survival heaters and thermostats shall be located external to the instrument housing. GSFC shall mount any necessary survival heaters on the spacecraft side of the LRO/CRaTER interface. These heaters will be used to maintain the CRaTER interface to within the survival limits listed in the LRO Thermal Systems Specification (431-SPEC-000091).

7.4 DECONTAMINATION HEATERS

CRaTER has no decontamination heaters.

8.0 THERMAL MODEL REQUIREMENTS AND FORMAT

BU will develop their thermal models using Thermal Desktop. Reduced Thermal Synthesizer System (TSS) and Systems Improved Numerical Differencing Analyzer (SINDA) models shall be developed for delivery to GSFC. The Lunar Reconnaissance Orbiter Thermal Math Model Requirements (431-RQMT-000092) 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.

LRO will deliver backload information for BU to input into their thermal model.

9.0 THERMAL VACUUM TEST CONSIDERATIONS

The purpose of this section is to encourage the CRaTER team 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 are not necessarily limited to, such items as test heaters or internal test temperature sensors as described below.

9.1 HIGH-VOLTAGE POWER SUPPLIES

CRaTER has a single 300 Volts Direct Current (VDC) detector high voltage (bias) supply.

9.2 TEST HEATERS

BU should consider that 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 objectives of the Orbiter TVAC test are to qualify the spacecraft design and achieve steady state and transient thermal balances. It may not be possible to do this with thermal targets alone. The BU and GSFC may decide to add test heaters as required. The best approach for successfully satisfying these objectives will be negotiated when the thermal vacuum test plans for the instrument and observatory are written.

During Orbiter TVAC testing, the CRaTER instrument will be kept within its survival limits at all times. No test heaters will be installed on the instrument to meet this requirement.

9.3 TEST SENSORS

Where there is a desire to monitor temperatures of internal components during TVAC, BU shall deliver CRaTER with the temperature sensor already installed. Temperature sensors used only during testing need not be flight qualified, but these sensors must meet outgassing, contamination and parts requirements so that they do not jeopardize the flight hardware or mission.

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

9.4 GREEN TAG ITEMS

Green tag items are those that must be installed prior to flight or environmental testing. CRaTER has no green tag items.

9.5 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 |
|----------------------------------|---|
| BU | Boston University |
| CCB | Configuration Control Board |
| CCR | Configuration Change Request |
| CM | Configuration Management |
| CMO | Configuration Management Office |
| CRaTER | Cosmic Ray Telescope for the Effects of Radiation |
| °C | Degrees Centigrade |
| GSE | Ground Support Equipment |
| GSFC | Goddard Space Flight Center |
| ICD | Interface Control Document |
| in/cm ² | Inch per centimeter squared |
| LPRP | Lunar Precursor and Robotic Program |
| LRO | Lunar Reconnaissance Orbiter |
| MIT | Massachusetts Institute of Technology |
| MLI | Multi-Layer Insulation |
| NASA | National Aeronautics and Space Administration |
| RQMT | Requirement |
| SINDA | Systems Improved Numerical Differencing Analyzer |
| SPEC | Specification |
| TCS | Thermal Control System |
| TICD | Thermal Interface Control Document |
| TSS | Thermal Synthesizer System |
| TVAC | Thermal Vacuum |
| V | Volts |
| VDC | Volts Direct Current |
| W/cm ² | Watts per centimeter squared |