431-RQMT-000092
Revision -
Effective Date: February 1, 2006
Expiration Date: February 1, 2011

Lunar Reconnaissance Orbiter

Thermal Math Model Requirements

August 12, 2005

LRO GSFC CMO

February 1, 2006

RELEASED

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

CM FOREWORD

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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 -	Released per 431-CCR-000030	C. Tooley	1/27/2006

List of TBDs/TBRs

Item No.	Location	Summary	Ind./Org.	Due Date
1	Table 5-1	Verification Matrix – review and update	C. Baker/ GSFC	12/31/2005
2	Appendix B	Traceability Matrix – populate table	C. Baker/ GSFC	12/31/2005

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1.0 INTRODUCTION

The purpose of this document is to provide the general requirements for preparing geometric math models (GMM) and thermal math models (TMM) of the spacecraft (SC) and instruments for the Lunar Reconnaissance Orbiter (LRO) Project.

1.1 REFERENCE DOCUMENTS

431-ICD-000084	LRO Instrument Mechanical Interface Control Document
431-ICD-000114	Lunar Reconnaissance Obiter to Lunar Reconnaissance Orbiter Camera Thermal Interface Control Document
431-ICD-000115	Lunar Reconnaissance Obiter to Lyman-Alpha Mapping Project Thermal Interface Control Document
431-ICD-000116	Lunar Reconnaissance Obiter to Diviner Thermal Interface Control Document
431-ICD-000117	Lunar Reconnaissance Obiter to Lunar Orbiter Laser Altimeter Thermal Interface Control Document
431-ICD-000118	Lunar Reconnaissance Obiter to Cosmic Ray Telescope for Effects of Radiation Thermal Interface Control Document
431-ICD-000119	Lunar Reconnaissance Obiter to Lunar Exploration Neutron Detector Thermal Interface Control Document
431-SPEC-000091	LRO Thermal Systems Specification

1.2 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 GEOMETRIC MATH MODELS

TMMR-1 Each Instrument Development Team (IDT) shall provide their respective instrument GMM in Thermal Synthesizer System (TSS) format version 11.01E or higher.

2.1 THERMAL SYNTHESIZER SYSTEM INPUT FILES

TMMR-2 The GMM shall be delivered with the following TSS files:

a. File containing the TSS geometry (*.tssgm)
b. A minimum of two files containing the hot and cold thermo-optical properties (*.tssop)
c. File containing the TSS material data (*.tssma). This can be just the TSS default file.

2.2 GEOMETRIC MATH MODELS FILE NAMING CONVENTION

TMMR-3 The geometry model and associated property and material files shall conform to the following naming conventions:

TMMR-4 TSS geometry file names shall have the format

INST_CONFIG_INTEXT_MMDDYY.TSSGM

where *INST* is the name of the instrument (e.g., Lyman-Alpha Mapping Project [LAMP], LRO Camera [LROC], etc.). *CONFIG* is used to designate the configuration as either "STOW" for stowed, "DEPL" for deployed, or "NA" for not applicable. *INTEXT* is used to designate whether the geometry model is internal ("INT"), external ("EXT"), or both ("BOTH"). *MMDDYY* is the date stamp.

TMMR-5 TSS thermo-optical property file names shall have the format

INST_PROP_MMDDYY.TSSOP

where *INST* is the name of the instrument (e.g., LAMP, LROC, etc.). *PROP* is used to designate whether the thermo-optical properties are "COLD", "HOT", or "NOM" for nominal properties. *MMDDYY* is the date stamp.

TMMR-6 TSS material property file names shall have the format

INST_MMDDYY.TSSMA

where *INST* is the name of the instrument (e.g., LAMP, LROC, etc.) and *MMDDYY* is the date stamp.

TMMR-7 All associated GMM files shall have the same date stamp. Even if one or more files have not changed, simply copy the file and rename it with the same date stamp as the other files. This will help to avoid any confusion with respect to file association.

2.3 MODEL COORDINATE SYSTEM

The LRO mechanical and thermal reference coordinate system is defined in the Lunar Reconnaissance Orbiter Mechanical Interface Control Document (431-ICD-000084).

TMMR-8 Unless otherwise noted, this document shall refer to the LRO reference coordinate system.

TMMR-9 All relevant (0,0,0) local origins shall be clearly identified in the model documentation that accompanies the model.

2.4 SURFACE AND ASSEMBLY NAMING CONVENTION

TMMR-10 All surfaces shall be placed in an assembly other than the “Model.1” default assembly. The surface and assembly names should reflect the subassembly, component or part being represented (e.g., LRO_ACS_RAD, LROC_NAC1_BAFFLE, etc.). Avoid using the default primitive names such as rectangle, cylinder, disc, etc.

2.5 THERMO-OPTICAL PROPERTIES

2.5.1 Lunar Reconnaissance Orbiter-Approved Thermo-Optical Properties

All proposed thermo-optical properties used must be approved by the GSFC coatings committee. A listing of the coatings and associated properties that have been approved by the GSFC Coatings Committee for use on LRO is provided in Section 5.2 of the Lunar Reconnaissance Orbiter Thermal Systems Specification (431-SPEC-000091). For the baseline analysis, the hot absorptance values for fourteen (14) months apply. IDT’s are by no means limited to these coatings. Candidate coatings not listed in the above referenced listing must be submitted to the LRO Lead Thermal Systems Engineer for approval.

2.5.2 Property Naming Convention

TMMR-40 Thermal coatings shall use the property naming convention per Section 5.2 of the Lunar Reconnaissance Orbiter Thermal Systems Specification (431-SPEC-000091).

TMMR-11 These property names shall be used where applicable. If it becomes necessary to add a coating not listed in the table, then assign a name to the coating using the convention described below.

Naming of thermo-optical properties should include as much information as possible to allow someone to easily ascertain what the coating is.

TMMR-12 All names shall be in lower case letters. This is shown in Table 2-1.

TMMR-13 In addition, to prevent accidental overwriting of similar property names upon model integration, each IDT shall preface the property names with the name of their instrument. Table 2-1 shows some examples of property names.

TMMR-41 New coatings not in the Lunar Reconnaissance Orbiter Thermal Systems Specification (431-SPEC-000091) shall be submitted to GSFC for thermal properties assessments and will be named jointly with the suppier.

Note: The thermo-optical properties of the proposed coating must be submitted to the LRO Thermal Systems Lead Engineer for approval.

Table 2-1. Example Thermo-Optical Property Names

PROPERTY NAME	DESCRIPTION
crater_germ_black_3mil	CRaTER instr. – 3-mil black Germanium
diviner_alum_kapton_3mil	Diviner instr. – 3-mil aluminized Kapton
lro_alum_tape_5mil	LRO SC – 5-mil aluminum tape
lola_vdg	LOLA instr. – vapor deposited gold
lro_k13c_composite	LRO SC – K13C composite

2.5.3 Submodel Naming Convention

TMMR-14 In order to avoid potential naming conflicts upon integration of all instrument models with the SC model, all GMMs delivered to GSFC shall utilize submodels. The obvious choice for the submodel name is that of the instrument (e.g., LEND, LAMP, LOLA, etc.). If warranted, more than one submodel may be used. In such cases, each submodel must be prefaced with the name of the instrument (e.g., LROC_SCS, LROC_WAC, etc.).

3.0 THERMAL MATH MODELS

TMMR-15 Each IDT shall deliver their respective instrument TMM in Systems Improved Numerical Differencing Analyzer SINDA/FLUINT format version 4.0 or higher.

3.1 SINDA/FLUINT INPUT FILES

TMMR-16 The TMM shall be delivered with the following SINDA/FLUINT files:

TMMR-17 Input file(s) shall be provided (*.inp). It is preferable that a single input file be provided containing logic for running hot, cold and safe-hold cases and be capable of carrying out both steady-state and transient analyses. However, if the logic for distinguishing between hot, cold, and survival cases is too cumbersome, then separate files for these cases will be allowed.

Information in the input file that will be replaced upon integration with the SC model should be placed in separate files and imported into the input data deck via “INCLUDE” or “INSERT” statements. The types of data affected are TSS generated orbital heat rates and radiation couplings.

TMMR-18 Temperature output files (*.out) shall be provided that were generated by executing the supplied input file.

TMMR-19 Separate output files shall be provided for the mission operational hot and cold cases and the relevant safe-hold case.

3.2 THERMAL MATH MODELS FILE NAMING CONVENTION

TMMR-20 The thermal models and associated support files shall conform to the following naming conventions:

TMMR-21 SINDA input data file names shall have the format

INST_CONFIG_INTEXT_MMDDYY.INP

where *INST* is the name of the instrument (e.g., LAMP, LROC, etc.). *CONFIG* is used to designate the configuration as either “STOW” for stowed, “DEPL” for deployed, or “NA” for not applicable. *INTEXT* is used to designate whether the thermal model is internal (“INT”), external (“EXT”), or both (“BOTH”). *MMDDYY* is the date stamp.

TMMR-22 SINDA temperature output file names shall have the format

INST_CONFIG_INTEXT_CASE_MMDDYY.OUT

where *INST*, *CONFIG*, and *INTEXT* are as described in (a) above. *CASE* is used to provide a short descriptor indicating what case was analyzed (e.g., COLD, HOT, SURV, BETA45, etc.). *MMDDYY* is the date stamp.

TMMR-23 Include file names for radiation coupling generated by TSS shall have the format

INST_CONFIG_INTEXT_CASE_MMDDYY.RADK

where *INST*, *CONFIG*, *INTEXT*, *CASE*, and *MMDDYY* are as described in (b) above.

TMMR-24 Include file names for environmental heat rate arrays and the associated VARIABLES 1 logic generated by TSS shall have the format

INST_CONFIG_CASE_MMDDYY.HR

where *INST*, *CONFIG*, *CASE*, and *MMDDYY* are as described in (b) above.

TMMR-25 All associated TMM files shall have the same date stamp. Even if one or more files have not changed, simply copy the file and rename it with the same date stamp. This will help to avoid any confusion with respect to file association.

3.3 THERMAL MODEL UNITS

TMMR-26 In order to avoid conflicts with units during model integration at the Orbiter level, all IDTs shall provide models utilizing the units listed in Table 3-1.

Table 3-1. Thermal Model Units

PARAMETER	UNITS
Power	Watts
Time	Seconds
Temperature	°C
Mass	Kilogram
Length	Meters
Area	m^2
Heat Flux	W/m^2
Material Density	kg/m^3

PARAMETER	UNITS
Specific Heat	W-sec/kg-°C (J/kg-°C)
Thermal Conductivity	W/m-°C
Thermal Capacitance	W-sec/°C (J/°C)
Conduction Couplings	W/°C
Radiation Couplings	m^2
Stefan-Boltzmann Constant	5.669×10^{-8} W/m^2-K^4

3.4 MODELING THE SPACECRAFT INSTRUMENT INTERFACE

TMMR-27 Integration of geometry and thermal math models for all instruments with the SC model shall be the responsibility of GSFC.

TMMR-28 To facilitate the integration effort, each IDT shall create an interface submodel named "IF". Each IDT is assigned a specific block of nodes to utilize. These are defined in Table 3-2.

Table 3-2. Interface Node Assignments

INSTRUMENT	I/F NODES
LEND	101, 102, 103, …..
LOLA (Optical Bench)	201, 202, 203, …..
LOLA (EBOX)	211, 212, 213, …..
LROC (NAC1)	301, 302, 303, …..
LROC (NAC2)	311, 312, 313, …..
LROC (WAC)	321, 322, 323, …..
LROC (SCS)	331, 332, 333, …..
CRaTER	401, 402, 403, …..
LAMP	501, 502, 503, …..

INSTRUMENT	I/F NODES
Diviner (Instrument)	601, 602, 603, …..
Diviner (DREB)	611, 612, 613, …..
Mini-RF (PA)	701, 702, 703, …..
Mini-RF (Main)	711, 712, 713, …..
Mini-RF (Antennae)	721, 722, 723, …..

As shown in Figure 3-1, the interface nodes simply serve as dummy nodes conductively coupling the instruments to the SC. The figure shows an example of coupling node <INSTR>.1 (one of the mounting pads) to the SC node SC.1 at the attach point via interface node IF.101. Conduction couplings, C1 and C2, will be specified by GSFC and the IDTs, respectively. If the IDT is responsible for providing the interface mounts, then the IDT will specify a realistic value for C2 and GSFC will specify a large value for C1 to simulate a hard mount and vice versa.

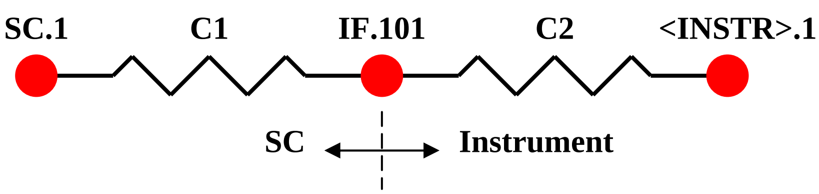

Figure 3-1. Typical Interface Conductive Coupling

3.5 SUBMODEL NAMING CONVENTION

TMMR-29 In order to avoid potential naming conflicts upon integration of all instrument models with the SC model, all TMMs delivered to GSFC shall utilize submodels. The obvious choice for the submodel name is that of the instrument (e.g., LEND, LAMP, LOLA, etc.). If warranted, more than one submodel may be used. In such cases, each submodel must be prefaced with the name of the instrument (e.g., LROC_SCS, LROC_WAC, etc.). It should be noted that SINDA limits submodel names to only 8 characters.

Since the output from TSS is used to feed into SINDA, please make sure that the submodel names used in TSS and SINDA agree with each other.

3.6 THERMAL MODEL RESTRICTIONS

3.6.1 Space Node

The global submodel name and node number assigned for space is SPACE.9999.

TMMR-30 All development teams shall use the global submodel name and node number assigned for space as SPACE.9999.

3.6.2 Register Data Block

SINDA/FLUINT allows users to define variable names in the Register Data Block that may be used in other Data Blocks.

TMMR-31 To avoid possible conflicts with other models, each development team shall preface any variables used with the name of their instrument.

3.6.3 Global User Data Block

The Global Data Block is reserved for use by GSFC.

TMMR-32 The IDTs shall use the Register Data Block to define any variables that may be needed.

3.6.4 Factor Cards

Factor Cards (FAC) in SINDA allow for an easy way of scaling values in the data blocks. This is most commonly used in Conductor Data Blocks to convert from one set of units to another. In the past, mistakes have been made where a conductor or group of conductors were added without checking for the presence of a FACs.

TMMR-33 To avoid the possibility of such mistakes, no FACs shall be allowed anywhere in the SINDA data deck.

3.6.5 Radiation Couplings

TMMR-34 Radiation couplings shall be provided in terms of areas utilizing units of square meters. The integrated model will specify a Stefan-Boltzmann constant of 5.669×10^{-8} W/m^2-°K^4.

3.6.6 Temperature Scale

TMMR-35 The temperature scale utilized shall be degrees Celcius.

TMMR-36 The ABSZRO parameter in SINDA shall have a value of -273.15.

3.6.7 Source Code

TMMR-37 No proprietary software code shall be allowed. All IDTs are required to provide source code for any logic used in the thermal models.

4.0 MODEL DOCUMENTATION

TMMR-38 All delivered geometry and thermal math models shall be documented in a user's manual in sufficient detail to permit independent analysis.

TMMR-39 The user's manual shall include, but not necessarily be limited to, the following information:

a. Graphical figures showing node locations and coordinate system
b. Graphical and/or table showing surface coatings matched to node numbers
c. Tables providing the following information

- Nodal thermal capacitance
- Linear node-to-node conductors
- Fixed radiation node-to-node conductors (if any). It is not necessary to include any radiation couplings generated by TSS.
- Array data not generated by TSS (e.g., temperature dependent properties, time varying power arrays, etc.)
- Listing of nodes where operational and survival heater power is to be applied, associated nodes used for heater control, maximum heater power, heater ON/OFF set points, type of heater (bang-bang or proportional), and mission mode power profiles.
- Detailed description of any special logic/algorithms utilized (e.g., heater control logic, Variable Conductance Heat Pipe [VCHP] logic, Capillary Pumped Loop [CPL]/Looped Heat Pipe [LHP] logic, etc.). No proprietary code will be allowed.
- Detailed description of logic and use for any user provided subroutines
- Description of user defined variables/registers along with where and how they are used
- Listing of component power dissipations and the nodes they are applied to
- Listing of materials used along with their applicable thermo-optical and material properties
- Listing correlating thermal model node(s) to each reference location where a spacecraft monitored temperature sensor will be placed

d. Table correlating SINDA node number to TSS object
e. Listing of temperature limits assigned to reference location(s) and other critical component. The appropriate node number(s) in the thermal model will be identified. The following three (3) types of temperature limits will be provided. Refer to the Lunar Reconnaissance Orbiter Thermal Systems Specification (432-SPEC-000091) for a description of these temperature limits.

- Survival limits
- Flight Design limits
- Qualification limits

The GMMs and TMMs will include an adequate level of detail to predict, under worst case hot, cold, and safe-hold conditions, all critical temperatures, including those that drive operational and survival temperature limits and heater power. 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, material differences, and degradation due to aging.

Models should use conservative property values for conduction, absorption, emission, and multi-layer insulation (MLI) effective emittance, and consider contact resistance. Analyses should consider cold and hot properties for external coatings.

Compliance with this requirement is at the discretion of the Thermal Systems Lead.

5.0 QUALIFICATION ASSURANCE PROVISIONS

5.1 GENERAL

All requirements in this document will be verified by one of the four methods defined below.

5.1.1 Analysis

The analysis method is used when:

- A rigorous, representative, and conclusive analysis is possible
- Test is not cost effective, and
- Inspection and demonstrations are not adequate

Analyses may include, but are not limited to, engineering analysis (which includes models and simulations), review of record, and similarity analysis.

5.1.1.1 Engineering Analysis

Engineering analysis may be quantitative, qualitative, or a combination of the two. Quantitative analysis involves the study and modeling of the physical entity whose performance is to be verified. Examples of quantitative analyses include end-to-end link analysis, structural (static and dynamic) analysis, thermal models, pointing knowledge and stability. Qualitative analyses are non-numerical and related to qualitative measure of performance, such as failure modes and effects analyses (FMEA), maintainability, and redundancy.

5.1.1.2 Validation of Records and Other Documentation Analysis

This kind of analysis uses design and manufacturing documentation to show compliance of design features and manufacturing processes. Validation of design documentation, e.g., engineering drawings, verifies that the "as-designed" hardware complies with contractual design and construction requirements. Validation of manufacturing records at end-item acceptance verifies that the "as-built" hardware has been fabricated per the approved design and associated documentation. Review and analysis of other documentation such as acceptance data packages and other compliance documentation of lower levels of assembly are valid analysis techniques.

5.1.1.3 Similarity Analysis

Similarity is included as a valid verification/qualification method. Qualification by similarity is used in lieu of test when it can be shown that an item is similar to, or identical in design to another item that has been previously qualified to equivalent, or more stringent requirements. Formal qualification documentation of the previously qualified item must be available for assessment when planning to qualify by similarity. Furthermore, an item whose design has been qualified by similarity must undergo acceptance verification to assess workmanship.

5.1.2 <u>Demonstration</u>

Demonstration is a verification method that provides a qualitative determination, rather than direct quantitative measurement, of the properties or functional characteristics of an end-item. The qualitative determination is made through observation with, or without test equipment or instrumentation.

5.1.3 <u>Inspection</u>

Inspection is the verification method used to verify construction features, workmanship, dimension, physical characteristics, and spacecraft conditions such as configuration, cleanliness, and locking hardware. Inspection also includes simple measurements such as length, and it is performed without the use of special laboratory or precision equipment. In general, requirements specifying function or performance are not verified by inspection.

5.1.4 <u>Test</u>

Verification by test consists of direct measurement of performance parameters relative to functional, electrical, mechanical, and environmental requirements. These measurements are obtained, during or after controlled application of functional and environmental stimuli to the test article, e.g., payload or satellite, and using instrumentation or special test equipment that is not an integral part of the test article being verified. The test activities include reduction and analysis of the test data, as appropriate. The following paragraphs define different categories of tests including performance, functional, environmental, interface, and structural tests.

5.1.4.1 Performance Test

A performance test consists of an individual test or series of electrical and/or mechanical tests conducted on flight, or flight-configured hardware and software at conditions equal to, or less than design specifications. Its purpose is to verify compliance of the test article with the stated applicable specification requirements that are verifiable by test. Typically, a full performance test is conducted at ambient conditions at the beginning and the end of a test sequence during which the test article is subjected to applicable environmental conditions, e.g., vacuum, high/low temperature extremes, or acoustics/random mechanical excitation.

5.1.4.2 Functional Tests

A functional test is a suitably chosen subset of a performance test. Typically, functional tests are conducted at ambient conditions between environmental exposures during the qualification or acceptance test sequence. The objective is to verify that prior to application of the next environment, exposure to the environment has not adversely affected the test article. When appropriate, functional tests, or a portion thereof, are conducted while the test article is exposed to a particular thermal or vacuum environment. Functional test, or a portion thereof, may also be conducted to assess the state of health of the hardware after major operations, such as transportation of flight hardware from one location to another.

5.1.4.3 Environmental Tests

Environmental testing is an individual test or series of tests conducted on flight, or flight-configured hardware to assure that flight hardware will perform satisfactorily after it is subjected to the induced launch environments, as well as its flight environment. Examples are: vibration, acoustic, temperature cycling, thermal vacuum and vacuum outgassing certification, and Electromagnetic Interference/Compatibility. Depending on the severity of the chosen environmental conditions, the purpose of the environmental exposure is to sufficiently stress the hardware so as to verify the adequacy of the design (protoflight levels and durations) or workmanship during fabrication (acceptance levels and durations).

5.1.4.4 Special Tests

Special tests are individual tests, or a series of tests conducted on flight, or flight-configured hardware to assure satisfactory performance of a particular critical element of the system, e.g., optical alignment. The special test verification category includes structural, mechanism and communication tests. Special tests may, or may not be performed in conjunction with environmental exposure.

5.1.4.5 Interface Tests

Interface tests verify the mechanical, electrical, and/or hardware-software interface between units and elements integrated into a higher level of assembly such as a module, subsystem, element, or a system.

5.1.4.6 Structural Tests

These tests are performed on structural elements, components, or assembled subsystems before delivery of the assembled structure to the integration and test organization. Structural tests designed to verify requirements of this specification may include: (1) static structural proof tests (to verify the strength/stiffness adequacy of the primary load path), and (2) dynamic tests, such as a modal survey or acoustic response test.

5.2 VERIFICATION MATRIX TABLE

The following matrix table defines the method of verification for all requirements contain in this document:

Table 5-1. Verification Matrix Table (TBR)

Verification Method:		Level:
Inspection	(I)	II System
Analysis	(A)	III Segment
Demonstration	(D)	IV Element
Test	(T)	V Subsystem

Requirement Number	Section Number	Object Heading	I	A	D	T	Responsible Org.
TMMR-1	2.0	Geometric Math Models					
TMMR-2	2.1	Thermal Synthesizer System Input Files					
TMMR-3	2.2	Geometric Math Models File Naming Convention					
TMMR-4	2.2	Geometric Math Models File Naming Convention					
TMMR-5	2.2	Geometric Math Models File Naming Convention					
TMMR-6	2.2	Geometric Math Models File Naming Convention					
TMMR-7	2.2	Geometric Math Models File Naming Convention					
TMMR-8	2.3	Model Coordinate System					
TMMR-9	2.3	Model Coordinate System					
TMMR-10	2.4	Surface and Assembly Naming Convention					
TMMR-11	2.5.2	Property Naming Convention					
TMMR-12	2.5.2	Property Naming Convention					
TMMR-13	2.5.2	Property Naming Convention					
TMMR-40	2.5.2	Property Naming Convention					
TMMR-41	2.5.2	Property Naming Convention					
TMMR-14	2.5.3	Submodel Naming Convention					
TMMR-15	3.0	Thermal Math Models					
TMMR-16	3.1	SINDA/FLUINT Input Files					
TMMR-17	3.1	SINDA/FLUINT Input Files					
TMMR-18	3.1	SINDA/FLUINT Input Files					
TMMR-19	3.1	SINDA/FLUINT Input Files					
TMMR-20	3.2	Thermal Math Models File Naming Convention					
TMMR-21	3.2	Thermal Math Models File Naming Convention					
TMMR-22	3.2	Thermal Math Models File Naming Convention					
TMMR-23	3.2	Thermal Math Models File Naming Convention					

Requirement Number	Section Number	Object Heading	I	A	D	T	Responsible Org.
TMMR-24	3.2	Thermal Math Models File Naming Convention					
TMMR-25	3.2	Thermal Math Models File Naming Convention					
TMMR-26	3.3	Thermal Model Units					
TMMR-27	3.4	Modeling the Spacecraft Instrument Interface					
TMMR-28	3.4	Modeling the Spacecraft Instrument Interface					
TMMR-29	3.5	Submodel Naming Convention					
TMMR-30	3.6.1	Space Node					
TMMR-31	3.6.2	Register Data Block					
TMMR-32	3.6.3	Global User Data Block					
TMMR-33	3.6.4	Factor Cards					
TMMR-34	3.6.5	Radiation Couplings					
TMMR-35	3.6.6	Temperature Scale					
TMMR-36	3.6.6	Temperature Scale					
TMMR-37	3.6.7	Source Code					
TMMR-38	4.0	Model Documentation					
TMMR-39	4.0	Model Documentation Content					

Appendix A. Abbreviations and Acronyms

Abbreviation/ Acronym	DEFINITION
ACS	Attitude Control System
CBE	Current Best Estimate
CCB	Configuration Control Board
CCR	Configuration Change Request
CM	Configuration Management
CMO	CM Office
CPL	Capillary Pumped Loop
CRaTER	Cosmic Ray Telescope of the Effects of Radiation
FAC	Factor Card
GMM	Geometric Math Models
GSFC	Goddard Space Flight Center
I/F	Interface
IDT	Instrument Development Team
LAMP	Lyman-Alpha Mapping Project
LEND	Lunar Exploration Neutron Detector
LHP	Looped Heat Pipe
LOLA	Lunar Orbiter Laser Altimeter
LRO	Lunar Reconnaissance Orbiter
LROC	LRO Camera
MLI	Multi-Layer Insulation
NA	Not applicable
NAC	Narrow Angle Component
RQMT	Requirement
SC	Spacecraft
SCS	Sequencing and Compressor System
SINDA	System Improved Numerical Differencing Analyzer
TBD	To be determined
TBR	To be reviewed/resolved
TMM	Thermal Math Models

Abbreviation/ Acronym	DEFINITION
TSS	Thermal Synthesizer System
VCHP	Variable Conductance Heat Pipe
WAC	Wide Angle Component
yr.	Year(s)

Appendix B. Traceability Matrix (TBD)

Parent Requirement			Requirement			Child Requirement		
RQMT#	**Section#**	**Object Heading**	**RQMT#**	**Section#**	**Object Heading**	**RQMT#**	**Section#**	**Object Heading**
			TMMR-1	2.0	Geometric Math Models			
			TMMR-2	2.1	Thermal Synthesizer System Input Files			
			TMMR-3	2.2	Geometric Math Models File Naming Convention			
			TMMR-4	2.2	Geometric Math Models File Naming Convention			
			TMMR-4	2.2	Geometric Math Models File Naming Convention			
			TMMR-5	2.2	Geometric Math Models File Naming Convention			
			TMMR-6	2.2	Geometric Math Models File Naming Convention			
			TMMR-7	2.2	Geometric Math Models File Naming Convention			
			TMMR-8	2.3	Model Coordinate System			
			TMMR-9	2.3	Model Coordinate System			
			TMMR-10	2.4	Surface and Assembly Naming Convention			
			TMMR-11	2.5.2	Property Naming Convention			
			TMMR-12	2.5.2	Property Naming Convention			

Parent Requirement			Requirement			Child Requirement		
RQMT#	**Section#**	**Object Heading**	**RQMT#**	**Section#**	**Object Heading**	**RQMT#**	**Section#**	**Object Heading**
			TMMR-13	2.5.2	Property Naming Convention			
			TMMR-40	2.5.2	Property Naming Convention			
			TMMR-41	2.5.2	Property Naming Convention			
			TMMR-14	2.5.3	Submodel Naming Convention			
			TMMR-15	3.0	Thermal Math Models			
			TMMR-16	3.1	SINDA/FLUINT Input Files			
			TMMR-17	3.1	SINDA/FLUINT Input Files			
			TMMR-18	3.1	SINDA/FLUINT Input Files			
			TMMR-19	3.1	SINDA/FLUINT Input Files			
			TMMR-20	3.2	Thermal Math Models File Naming Convention			
			TMMR-21	3.2	Thermal Math Models File Naming Convention			
			TMMR-22	3.2	Thermal Math Models File Naming Convention			
			TMMR-23	3.2	Thermal Math Models File Naming Convention			
			TMMR-24	3.2	Thermal Math Models File Naming Convention			
			TMMR-25	3.2	Thermal Math Models File Naming Convention			

Parent Requirement			Requirement			Child Requirement		
RQMT#	Section#	Object Heading	RQMT#	Section#	Object Heading	RQMT#	Section#	Object Heading
			TMMR-26	3.3	Thermal Model Units			
			TMMR-27	3.4	Modeling the Spacecraft Instrument Interface			
			TMMR-28	3.4	Modeling the Spacecraft Instrument Interface			
			TMMR-29	3.5	Submodel Naming Convention			
			TMMR-30	3.6.1	Space Node			
			TMMR-31	3.6.2	Register Data Block			
			TMMR-32	3.6.3	Global User Data Block			
			TMMR-33	3.6.4	Factor Cards			
			TMMR-34	3.6.5	Radiation Couplings			
			TMMR-35	3.6.6	Temperature Scale			
			TMMR-36	3.6.6	Temperature Scale			
			TMMR-37	3.6.7	Source Code			
			TMMR-38	4.0	Model Documentation			
			TMMR-39	4.0	Model Documentation Content			

NOTE: Each Requirement must have its own Object Heading.