Robotic Lunar Exploration Program

Lunar Reconnaissance Orbiter (LRO)

LRO Orbiter Reduced Spacecraft Thermal Model Report

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TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

1.0 <u>INTRODUCTION</u>

This report documents the Lunar Reconnaissance Orbiter (LRO) reduced geometric math model (RGMM) and reduced thermal math model (RTMM) for the current baseline configuration. The LRO Orbiter configuration is shown in Figure 1-1 and the reduced model configurations are illustrated in Figures 1-2 and 1-3.

1.1 PURPOSE

The purpose of this report is to provide a detailed description of the reduced Orbiter thermal models. These models provide a representation of the spacecraft in the vicinity of the Diviner, CRaTER, and Mini-RF instruments. These models are intended to be used by the Diviner, CRaTER, and Mini-RF Instrument Development Teams (IDT) to perform their detailed thermal analyses for the Beta 0° hot, Beta 90° cold, and Beta 90° survival cases.

1.2 MODEL FORMATS

The RGMM was developed utilizing the Thermal Synthesizer System (TSS) program. The RTMM was developed utilizing the Systems Improved Numerical Differencing Analyzer (SINDA) program.

1.3 THERMAL MODEL FILES

Table 1-1 provides a listing of the files that accompany this report as well as a description of each file. These files contain the geometry and thermal math models.

Table 1-1: Thermal Model Files

FILE NAME	DESCRIPTION
Lro_red_sc_03_21_06.tssgm	Reduced TSS geometry file (Beta 90 oper. config.)
Lro_red_sc_surv_03_21_06.tssgm	Reduced TSS geometry file (Beta 90 surv. config.)
Lro_cold_03_21_06.tssop	TSS cold case thermo-optical property file
Lro_hot_03_21_06.tssop	TSS hot case thermo-optical property file
Lro_03_21_06.tssma	TSS material property file (dummy file)
Lro_red_sc_b00hot_03_21_06.inp	SINDA thermal model (Beta 0 hot oper. case)
Lro_red_sc_b90cold_03_21_06.inp	SINDA thermal model (Beta 90 cold oper. case)
Lro_red_sc_b90surv_03_21_06.inp	SINDA thermal model (Beta 90 cold surv. case)
B0_hot.radk	Beta 0° hot oper. case RADK include file
B90_cold.radk	Beta 90° cold oper. case RADK include file
B90_cold_surv.radk	Beta 90° cold surv. case RADK include file
B0_hot.hr	Beta 0° hot oper. case heat rate include file
B90_cold.hr	Beta 90° cold oper. case heat rate include file
B90_cold_surv.hr	Beta 90° cold surv. case heat rate include file
B0_hot_tran_btemp.txt	Beta 0° hot oper. case S/C bound. temp. include file
B90_cold_ss_btemp.txt	Beta 90° cold oper. case S/C bound. temp. include file
B90_cold_surv_btemp.txt	Beta 90° cold surv. case S/C bound. temp. include file
B0_hot_tran.out	Sample hot oper. case transient output file
B90_cold_ss.out	Sample cold oper. case steady-state output file
B90_surv_tran.out	Sample cold surv. case transient output file

FILE NAME	DESCRIPTION
Beta0.tssan	TSS animation setup for Beta 0° orbit
Cb90_70km.tssor	TSS orbital setup for Beta 90° operational orbit
Cb90_70km_surv.tssor	TSS orbital setup for Beta 90° survival orbit
Hb00_30km.tssor	TSS orbital setup for Beta 0° operational orbit

1.4 APPLICABLE DOCUMENTS

The documents that form a part of this reduced thermal model report, to the extent specified herein, are provided in Table 1-2.

Table 1-2: Applicable Documents

DOCUMENT NO.	TITLE
GSFC-STD-7000	"General Environmental Verification Specification for STS and ELV Payloads, Subsystems and Components"
431-RQMT-000092	"LRO Thermal Math Model Requirements"

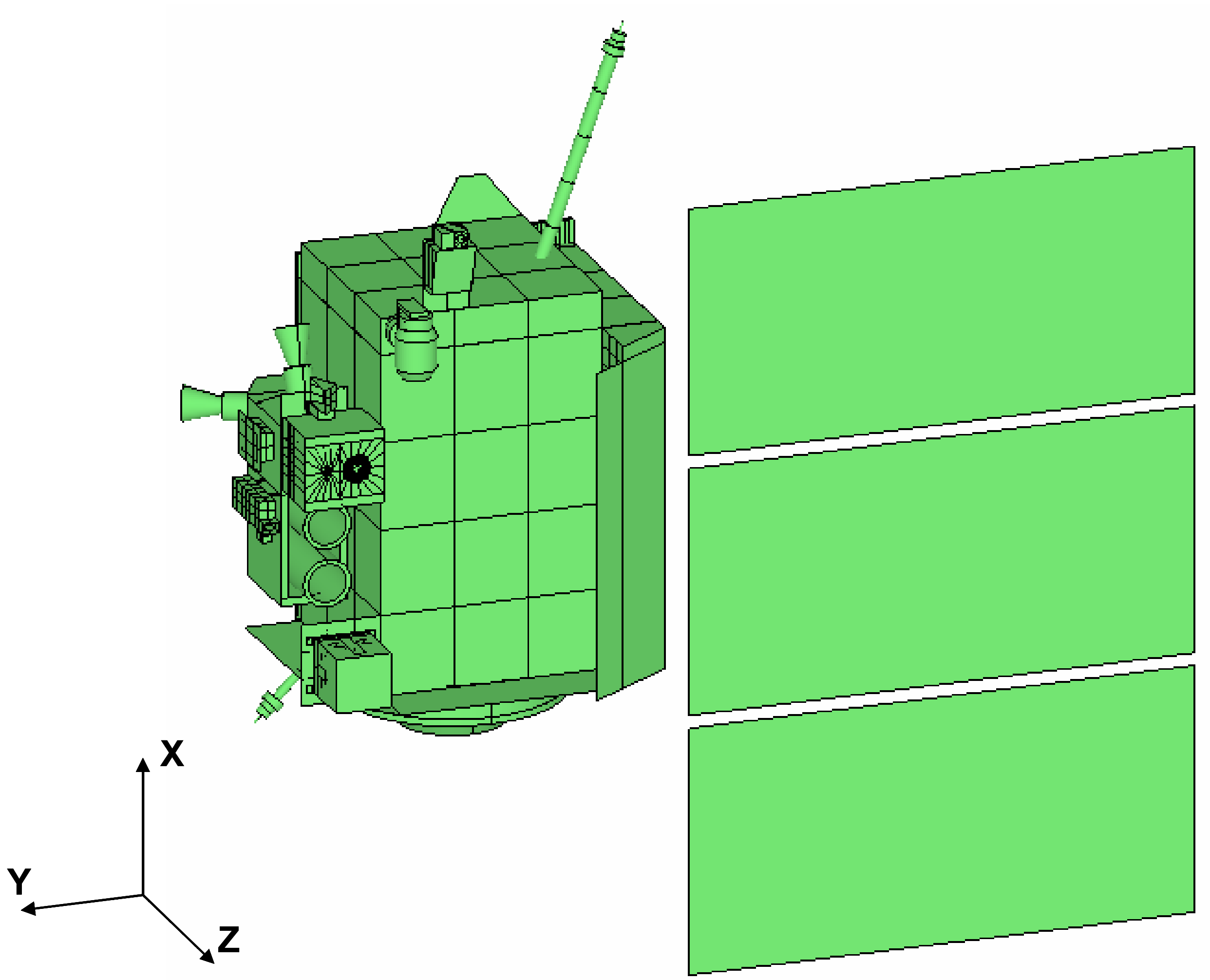

Figure 1-1: LRO Configuration

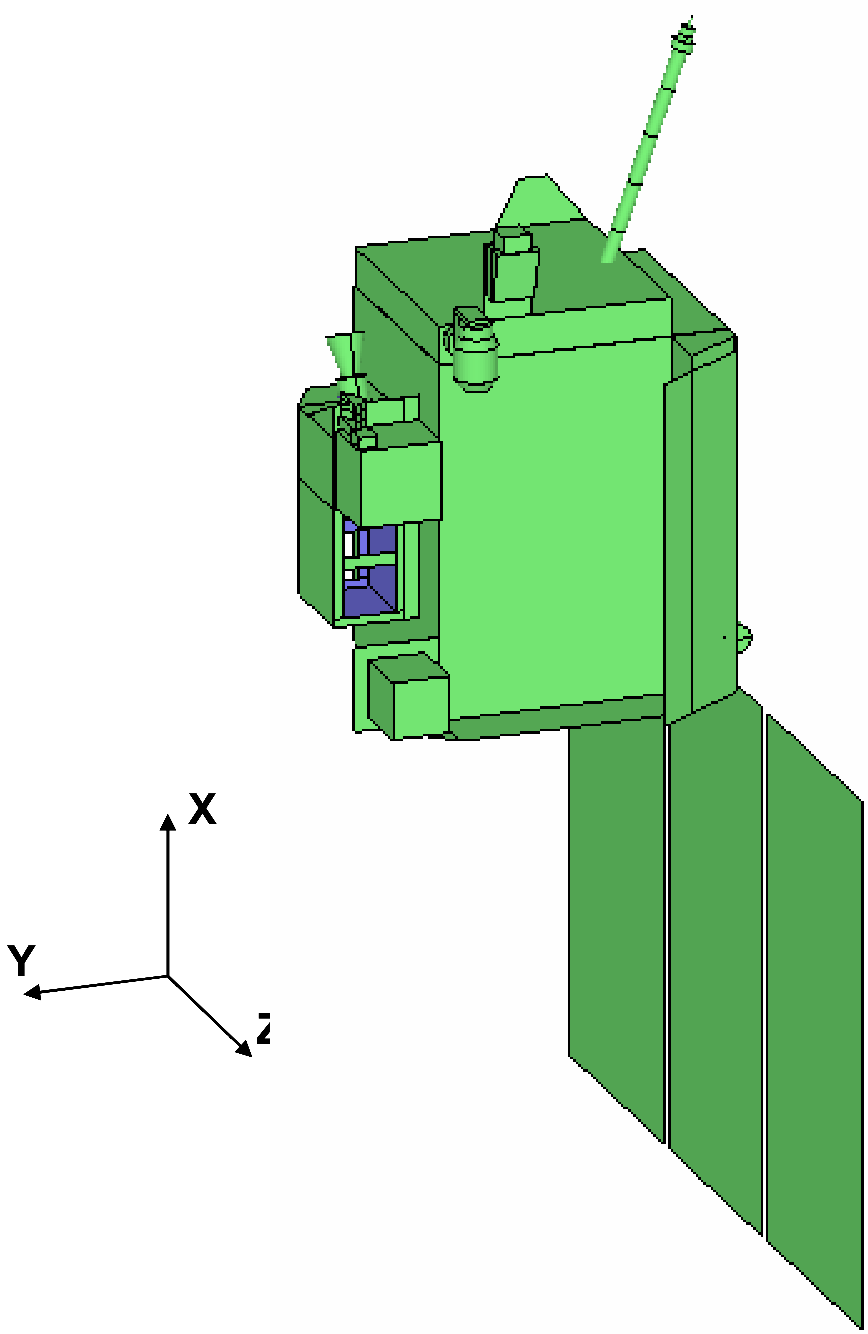

Figure 1-2: LRO Reduced Model (Beta 90° Cold Oper. Configuration)

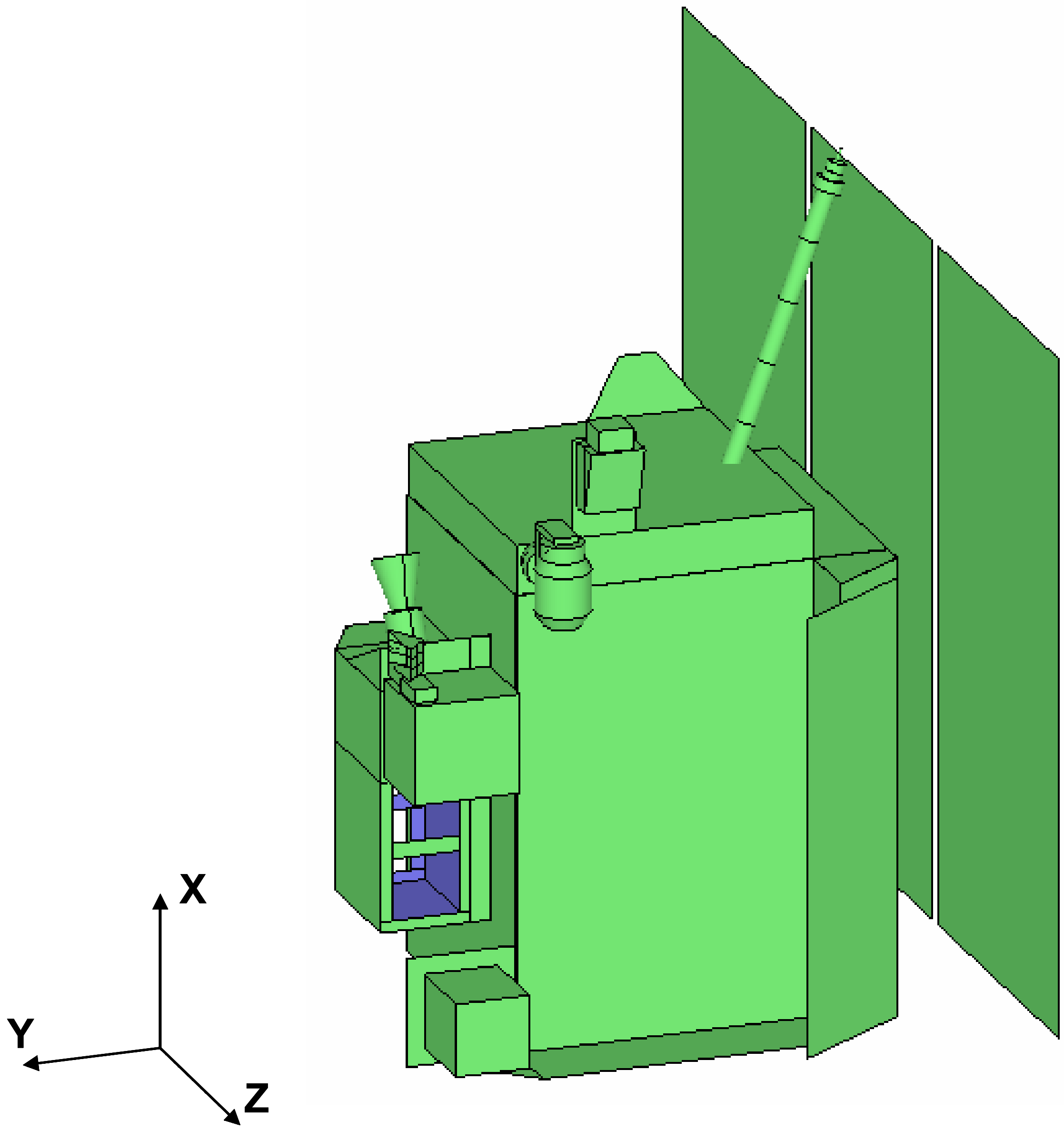

Figure 1-3: LRO Reduced Model (Beta 90° Cold Survival Configuration)

2.0 MODEL UNITS AND THERMAL PROPERTIES

The units utilized in the thermal math model are listed in Table 2-1.

Table 2-1: Model Units

PARAMETER	UNIT
Time	Seconds
Length	Meter
Power	Watts
Temperature	°C
Conductance	W/°C
Radiation Coupling	M^2
Capacitance	Watt-sec/°C

The thermo-optical properties used in the model are listed in Table 2-2.

Table 2-2: Thermo-Optical Properties

DESCRIPTION	COLD		HOT 13 mo. (5 yr.)		SPEC.	
	α_S	ε_H	α_S	ε_H	SOL	IR
Coatings						
Black Anodize	0.80	0.88	0.92	0.83		
Irridite Aluminum	0.10	0.19	0.25	0.11		
Z307 Conductive Black	0.95	0.89	0.97	0.85		
MSA94B Conductive Black	0.94	0.91	0.96	0.87		
Z306 Black	0.94	0.89	0.95	0.85		
Z93P White Paint	0.17	0.92	0.25 (0.36)	0.87		
NS43C Conductive White	0.20	0.91	0.26 (0.37)	0.87		
VDA (Vapor Dep. Alum.)	0.08	0.05	0.10	0.03	0.98	0.98
VDG (Vapor Dep. Gold)	0.19	0.03	0.21	0.02		
Films & Tapes						
Kapton, 3-mill	0.45	0.80	0.51 (0.60)	0.76		
OSR Pilkington, 5-mil	0.07	0.80	0.12 (0.19)	0.78	1.0	---
OSR/ITO Pilkington, 5-mil	0.08	0.80	0.15 (0.23)	0.78		
Silver Teflon Tape, 5-mil	0.08	0.78	0.25 (0.33)	0.73	1.0	---
Silver Teflon Tape, 10-mil	0.09	0.87	0.27 (0.35)	0.83	1.0	---
Silver Teflon, 5-mil	0.08	0.78	0.11 (0.14)	0.73		

DESCRIPTION	COLD		HOT 13 mo. (5 yr.)		SPEC.	
	α_S	ε_H	α_S	ε_H	SOL	IR
Silver Teflon, 10-mil	0.09	0.87	0.13 (0.17)	0.83		
Black Kapton, 3-mil	0.91	0.81	0.93	0.78		
Germanium Black Kapton	0.49	0.81	0.51	0.78		
Miscellaneous						
Solar Cell Triple Junction	0.86	0.87	0.90	0.77	1.0	---
M55J Composite, Bare	0.90	0.79	0.93	0.75		
K1100 Composite, Bare	0.88	0.71	0.88	0.71		
Internal Fuel Line	1.0	0.15	1.0	0.15		

3.0 HOW TO USE THE MODELS

The thermal models provided represent the current baseline configuration. The TSS geometry file and SINDA thermal model file contain reduced representations for the S/C and Optical Bench that are relevant for performing detailed analyses for the Diviner, CRaTER and Mini-RF instruments. All S/C surfaces that do not come into play have been removed.

3.1 TSS GEOMETRY MODEL

The geometry model includes simple representations of all the instruments. Each IDT should substitute their detailed geometry for the simplified one.

Note that two geometry files are provided. The solar array configuration in each has been setup for Beta 90° cold operational case and Beta 90° cold survival case. The solar array articulation is setup in the Beta0.tssan directory.

3.2 SINDA THERMAL MODEL

The SINDA models are complete and may be run as is. Prior to making any modifications, each instrument team should run the models as received and compare the temperature output files with the output files provided by Goddard Space Flight Center (GSFC). The purpose of this is to verify that the files were not somehow corrupted in the transfer process.

Once the integrity of the files has been verified, each instrument team should replace the representation of their instrument in the RTMM with the appropriate detailed model. Note that the instrument-to-S/C interface couplings were not included in the model. Each IDT will need to provide the appropriate interface couplings. Interface couplings must be to the spacecraft (submodel=PROPPNL for Diviner/CRaTER and AVPNL for Mini-RF) 1xxx series nodes. The 9xxx and 8xxx series nodes represent MLI.

The SINDA model also contains RADK and Heat Rate data generated by TSS. This information is contained in two (2) 'INCLUDE' files with a .RADK and .HR file extension. You will need to replace these with new RADK and Heat Rate files after you run TSS. All other conduction and radiation couplings in the main SINDA files must be left intact.

The cold operational case thermal model has been setup based on a Beta 90° orbit at 70 km altitude. Since the geometry and environment do not change with respect to orbit position, only steady-state boundary temperatures are provided for the S/C structural nodes.

The hot operational case thermal model has been setup based on a Beta = 0° orbit at 30 km altitude. Transient boundary temperatures have been provided for the S/C structural nodes. These are located in the BTEMP submodel.

The cold survival case thermal model has been setup based on a Beta 90° orbit at 70 km altitude. However, unlike the cold operational case, the S/C is orbiting in a solar inertial mode, therefore, transient boundary temperatures have been provided for the S/C.

4.0 S/C DESCRIPTION (SUBMODELS = PROPPNL, AFTDECK)

The portions of the S/C that were included in this reduced model are illustrated in Figure 4-1. In eliminating the bulk of the S/C model that does not have an impact on Diviner, CRaTER and Mini-RF, it was necessary for us to specify the portions of the S/C that was included as boundary nodes. These are labeled in Figure 4-1 with node numbers less than 2000. The 8000 and 9000 series nodes represent MLI. You will note that both steady-state and transient boundary temperatures are provided for the hot case but only steady-state boundary temperatures are provided in the cold operational and survival cases.

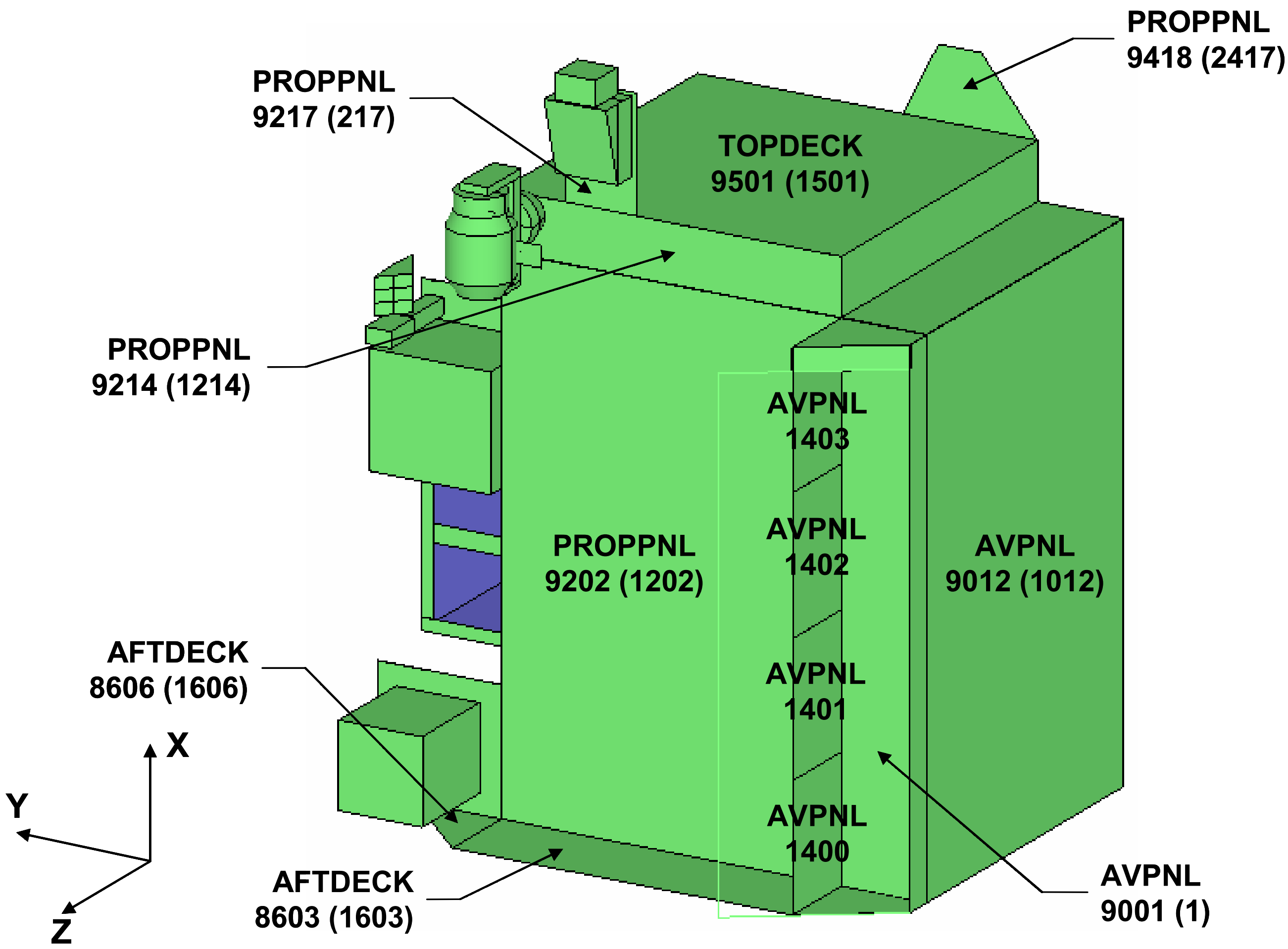

Figure 4-1: S/C Nodes

4.1 LRO ORBITS

The baseline orbit for the hot operational case is currently specified as Beta 0°, 30 km altitude, hot thermo-optical properties and hot environmental constants. LRO flies in a lunar oriented configuration. The subdirectory entitled "HB00_30KM.TSSOR" is provided and is already setup for this orbit. The correct lunar IR flux is also included ranging from 1335 W/m^2 at the sub-solar point to 5.2 W/m^2 at the poles and while in eclipse.

The baseline orbit for the cold operational case is currently specified as Beta 90°, 70 km altitude, cold thermo-optical properties and cold environmental constants. LRO flies in a lunar oriented configuration. The subdirectory entitled "CB90_70KM.TSSOR" is provided and is already setup for this orbit. The lunar IR flux is specified as a constant at 5.2 W/m^2.

The baseline orbit for the cold survival case is the same as the cold operational case described above. However, the orientation of the solar array is different and LRO flies in a solar inertial mode. The subdirectory entitled "CB90_70KM_SURV.TSSOR" is provided and is already setup for this orbit. The lunar IR flux is specified as a constant at 5.2 W/m^2.

4.2 SOLAR ARRAY ARTICULATION

Of the three cases provided, the solar array only articulates for the Beta 0° hot case. The articulation of the solar array is provided and is setup in the subdirectory entitled "BETA0.TSSAN". Articulation is setup for twelve points in the orbit. You should not have to manipulate this file.

APPENDIX A: ABBREVIATIONS AND ACRONYMS

Abbreviation/ Acronym	DEFINITION
°C	Degrees Celsius
C_p	Specific heat
CBE	Current Best Estimate
GSFC	Goddard Space Flight Center
ICD	Interface Control Document
IDT	Instrument Development Team
I/F	Interface
J	Joules
k	Thermal Conductivity
°K	Degrees Kelvin
Kg	Kilogram
LAMP	Lyman-Alpha Mapping Project
LEND	Lunar Exploration Neutron Detector
LOLA	Lunar Orbiter Laser Altimeter
LROC	Lunar Reconnaissance Orbiter Camera
LRO	Lunar Reconnaissance Orbiter
M	Meters
MLI	Multi-Layer Insulation
NAC	Narrow Angle Component
NASA	National Aeronautics and Space Administration
OB	Optical Bench
ρ	Density
RGMM	Reduced Geometric Math Model
RTMM	Reduced Thermal Math Model
S/C	Spacecraft
SCS	Sequencing & Compressor System
Sec	Seconds
SINDA	Systems Improved Numerical Differencing Analyzer
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
W	Watts
WAC	Wide Angle Component
yrs.	Years