Lunar Reconnaissance Orbiter (LRO) Instrument Accommodations Review April 28, 2005

Thermal Design

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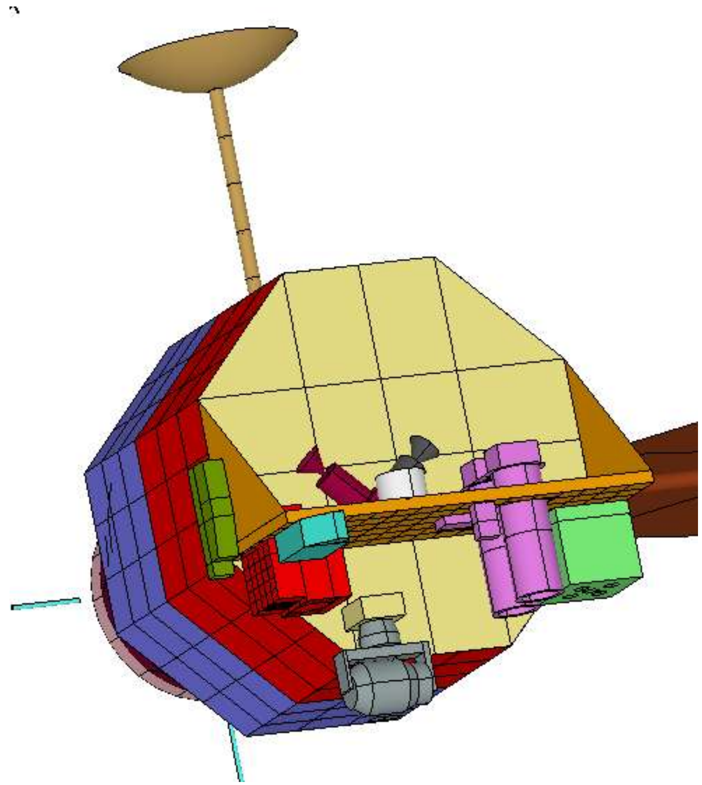
Agenda

- Status of Instrument Module Design
- Status of Trades with instruments
- Heater Placement Philosophy
- System Thermal Modeling Overview
- Model trends: LAMP, LROC, LOLA, CRaTER, LEND, Diviner
- Requirements
- Upcoming due dates
- Thermal Issues to consider

State of the Design of the Instrument Module



- Mechanical Design Baseline
  - Modeled per G. Rosanova Design E electronic drawing (#E LRO ASSY-MP.exe) Instruments Received 4/13
- Instrument Module is expected to change layout (LROC, CRaTER)

Status of Trades on the Instruments

- CRaTER
  - CRaTER to evaluate operational temperature requirements at detectors
  - CRaTER shall evaluate isolating detector from electronics housing
  - CRaTER shall evaluate isolating the instrument from LRO
- Diviner
  - Thermal design of Diviner needs to be initiated
  - Need to evaluate dissipated power locations and temperature gradient requirements
  - Investigate relocating electronics box to the zenith side of the radiator and isolating it
- LAMP
  - LAMP is located on the anti-sun side gusset and is loosely coupled to LRO
  - Currently using 0.8 W/ºC/mount per SwRI
  - LAMP shall evaluate isolating the instrument from LRO
- LEND
  - Thermal design of LEND needs to be initiated
  - Need to understand couplings between electronics and detectors to minimize transients
  - LEND shall evaluate isolating the instrument from LRO
- LOLA
  - Clear field of view has been provided for the Laser/Detector bench radiator
    - Laser/Detector bench is now isolated from LRO
  - MEB was moved up to the zenith side
    - MEB has its own Zenith radiator but is also coupled to the Optical Bench/Radiator
    - MEB thermal design is a work in progress (may be isolated from LRO)
- LROC
  - Clear field of view for NACs, WAC, and SCS to zenith side has been provided
  - LROC is now isolated from LRO

Joint Modeling Activity

- CRaTER
  - No models available to date
  - Using GSFC developed models based on information extracted from the proposal and information gathered at the TIM
- Diviner
  - No Diviner specific models available (waiting on reduced models and documentation)
  - Using GSFC developed models based on information extracted from the proposal
- LAMP
  - Preliminary models have been provided but appear to have a radiative coupling to the surface below LAMP that has some system implications
  - Using GSFC developed models based on information extracted from the proposal Model documentation and information gathered at the TIM
- LEND
  - No models available
  - Using GSFC developed models based on information extracted from the proposal
- LOLA
  - Preliminary TSS/SINDA models exchanged regularly between GSFC LOLA team and GSFC LRO team
- LROC
  - Preliminary TSS/SINDA models have been provided for the NACs
  - Using GSFC developed models of the WAC and SCS based on information extracted from the proposal

Changes Since Instrument Kickoff

- LOLA
  - Isolated Optical Bench
  - Possibly isolated electronics
- LROC
  - All components isolated combined on a single plate
  - De-Contamination Heater Added
- LAMP
  - Location has been moved to anti-sun side gusset
- CRaTER
  - CRaTER has grown in size
- Diviner
  - Separate electronics box required
- LEND
  - No changes known

Heater Placement Philosophy

- Thermally Isolated Components
  - Isolated instrument shall locate survival heater on the instrument itself and use the instrument survival heater bus (uncontrolled)
  - Isolated instrument shall locate operational heaters on the instrument itself and use the instrument operational heater bus (uncontrolled)
  - Temperature requirements at the optical bench interface shall be relaxed to account for isolation
  - Advantage to instruments is tighter thermal control

- Thermally Coupled Components
  - Heaters may be more efficient on the instrument than the bench (design should be traded)
  - Actual temperature requirement on bench irrelevant, need to control instrument temperature only (thru joint modeling), but bench will run similar temperature
  - Last minute thermal fixes become more difficult
  - Disadvantage is more system couplings

Suggested Optimizations – Component/Instrument

- Instrument operational heaters and survival heaters need to be located on the instrument (transferring heat through the interface is inefficient)
- Optical Bench temperature requirements are less important than instrument temperature requirements, so maintain the instrument via heaters reduces the bench requirements (heaters will be sized for the system)
- Instruments will be radiatively decoupled from the bench with a blanket
- CRaTER, Diviner and LEND should conduct trade studies to isolate themselves from the optical bench in order to gain tighter temperature control
- Orbit transients need to be carefully analyzed

Thermal Documentation Status

- **Lunar Reconnaissance Orbiter (LRO) General Thermal Subsystem Specification** (431-SPEC-000091) – Release Date 5/15
  - General Requirements that apply to all thermal components and instruments for assumptions, requirements, analysis, testing, GSE hardware required
- **Instrument ICDs (in-draft)**

  431-ICD-000114 LROC Thermal Interface Control Document

  431-ICD-000115 LAMP Thermal Interface Control Document

  431-ICD-000116 Diviner Thermal Interface Control Document

  431-ICD-000117 LOLA Thermal Interface Control Document

  431-ICD-000118 CRaTER Thermal Interface Control Document

  431-ICD-000119 LEND Thermal Interface Control Document
- **Lunar Reconnaissance Orbiter (LRO) Thermal Math Model Requirements** (431-RQMT-000092)– Release Date 5/15 and available today

Model Requirements Overview

- Models delivered to GSFC shall adhere to **Lunar Reconnaissance Orbiter (LRO) Thermal Math Model Requirements** (431-RQMT-000092)
- Reduced geometric math models shall be delivered to GSFC in Thermal Synthesizer System (TSS) format version 11.01E or higher
- Reduced thermal math models shall be delivered to GSFC in SINDA/FLUINT format version 4.0 or higher
- File naming conventions apply
  - As an example, geometry file names shall have the format

INST_CONFIG_INTEXT_MMDDYY.TSSGM

where: ***INST***: name of instrument (e.g., LROC, LAMP, etc.)

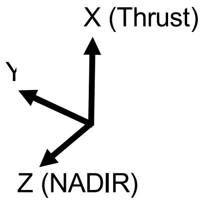
CONFIG: "STOW" for stowed, "DEPL" for deployed, "NA" for not applicable

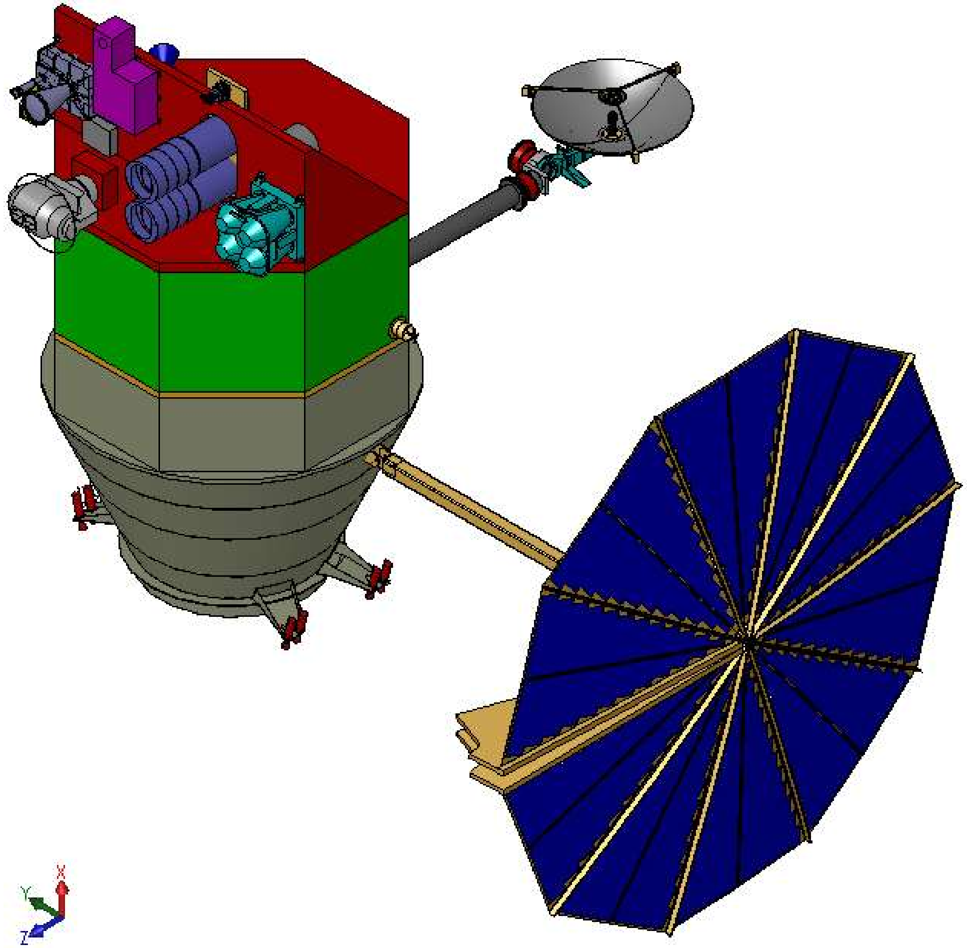
INTEXT: "INT" for internal, "EXT" for external, "BOTH" for both

MMDDYY: month/day/year date stamp

Model Coordinate System

- All geometry models shall utilize the LRO Mechanical Coordinate System definition





Thermo-Optical Property Listing

NAME	DESCRIPTION	COLD		HOT 13 mo. (5 yr.)	
		α_S	ε_H	α_S	ε_H
lro_black_anodize	Black Anodize	0.80	0.88	0.92	0.83
lro_clear_anodize	Clear Anodize	TBD	TBD	TBD	TBD
lro_irridite	Irridite	0.10	0.19	0.25	0.11
lro_z307_cond_black	Z307 Conductive Black	0.95	0.89	0.97	0.85
lro_msa94b_cond_black	MSA94B Conductive Black	0.94	0.91	0.96	0.87
lro_z306_black	Z306 Black	0.94	0.89	0.95	0.85
lro_z93p_white	Z93P White Paint	0.17	0.92	0.25(0.36)	0.87
lro_ns43c_cond_white	NS43C Conductive White	0.20	0.91	0.26(0.37)	0.87
lro_vda	Vapor Deposited Aluminum	0.08	0.05	0.10	0.03
lro_vdb	Vapor Deposited Beryllium	TBD	TBD	TBD	TBD
lro_kapton_3mil	Kapton, 3-mill	0.45	0.80	0.51(0.60)	0.76
lro_osr_pilkington_5mil	OSR Pilkington, 5-mill	0.07	0.80	0.12(0.19)	0.78
lro_osr_ito_pilkington_5mil	OSR/ITO Pilkington, 5-mill	0.08	0.80	0.15(0.23)	0.78
lro_ag_tef_tape_5mil	Silver Teflon Tape, 5-mil	0.08	0.78	0.25(0.33)	0.73
lro_ag_tef_tape_10mil	Silver Teflon Tape, 10-mil	0.09	0.87	0.27(0.35)	0.83
lro_ag_tef_5mil	Silver Teflon, 5-mil	0.08	0.78	0.11(0.14)	0.73
lro_ag_tef_10mil	Silver Teflon, 10-mil	0.09	0.87	0.13(0.27)	0.83
lro_black_kapton_3mil	Black Kapton, 3-mil	0.91	0.81	0.93	0.78
lro_germ_black_kapton	Germanium Black Kapton	0.49	0.81	0.51	0.78
lro_solar_cell	Solar Cell Triple Junction	0.86	0.87	0.90	0.77
lro_m55j_composite	M55J Composite, Bare	0.90	0.79	0.93	0.75
lro_k1100_composite	K1100 Composite, Bare	0.88	0.71	---	---
lro_fused_silica	Fused Silica	TBD	TBD	TBD	TBD
lro_sapphire	Sapphire Lens	TBD	TBD	TBD	TBD

- This list of thermo-optical properties listed have been approved by the GSFC Coatings Committee for use on LRO.
- Proposed coatings not on the list must be submitted to Charles Baker (LRO Lead Thermal Systems Engineer) for approval. Samples may be requested for testing if data on the coating is not available.

Thermal Model Units

- Units utilized in the LRO S/C thermal model are presented in the table shown
- For consistency, all delivered thermal models shall utilize this set of units
- No “FAC” cards are allowed!

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
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

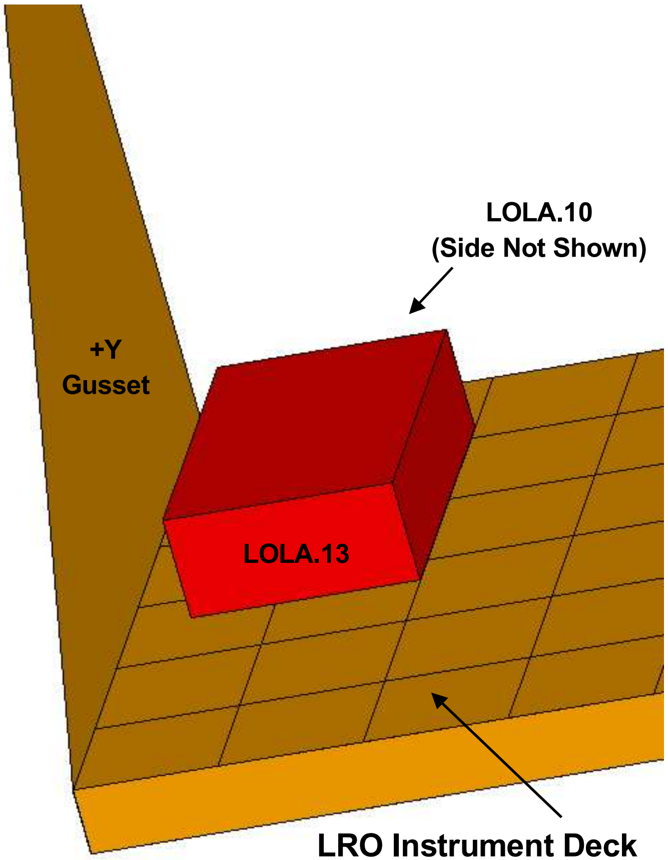
Model Documentation

- All delivered GMMs and TMMs shall be accompanied by model documentation per **Lunar Reconnaissance Orbiter (LRO) Thermal Math Model Requirements** (431-RQMT-000092)
- Document will include but not limited to the following. Refer to model requirements document for specific details.
  - Figures with node numbers labeled
  - Figures or tables showing thermo-optical coatings matched to node numbers
  - Tables listing the following:
    - Nodal thermal capacitance
    - Linear and radiation couplings
    - Array data (if any)
    - Nodes where operational and survival heaters are located, associated control node, heater size, heater type (on/off or proportional), thermostat set points
    - Power dissipations and associated node locations
    - Critical nodes and associated op./surv. temperature limits
    - Description of any special logic and/or software code utilized
    - Hot/cold thermo-optical properties and material properties (specific heat, density, conductivity)

Instrument Trends – LOLA MEB

- MEB is probably growing
- MEB will need operational and survival heater power – best done on MEB
- Design/modeling is on going
- Estimated steady-state heater power required on the LRO Instrument Deck is ~22 Watts (cold case)

	Hot Case (Beta 0°)			Heater Power
Node	Transient Max	Steady-state	Transient Min	(Watts)
10	42.4	20.4	-0.4	
13	38.4	17.9	-1.8	0
	Cold Case (Beta 90°)			Heater Power
Node	Transient Max	Steady-state	Transient Min	(Watts)
10	0.9	0.9	0.9	
13	0.8	0.8	0.8	22.3*



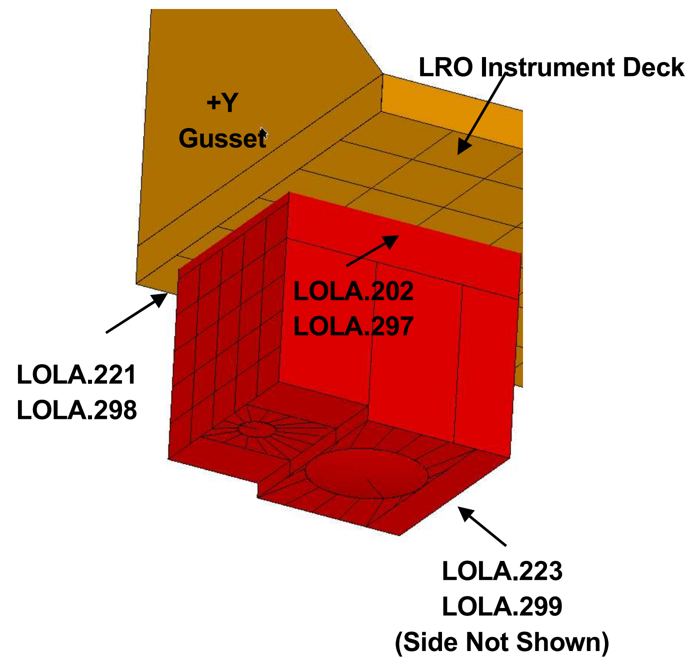
*Note: Heater nodes located on the LRO Instrument Deck maintain MEB temperatures in the cold case.

Instrument Trends – LOLA Laser Housing

	Hot Case (Beta 0°)			Heater Power
Node	Transient Max	Steady-state	Transient Min	(Watts)
202	21.6	15.9	9.3	0
221	18.8	12.0	4.5	
223	19.0	12.0	4.7	
297	21.4	15.8	9.5	
298	18.7	12.0	4.5	
299	18.9	12.2	4.8	
	Cold Case (Beta 90°)			Heater Power
Node	Transient Max	Steady-state	Transient Min	(Watts)
202	-54.1	-57.0	-58.3	3.3*
221	-56.9	-60.0	-61.3	
223	-56.9	-60.0	-61.2	
297	-53.7	-57.0	-57.9	
298	-56.5	-59.9	-60.8	
299	-56.4	-59.6	-60.7	

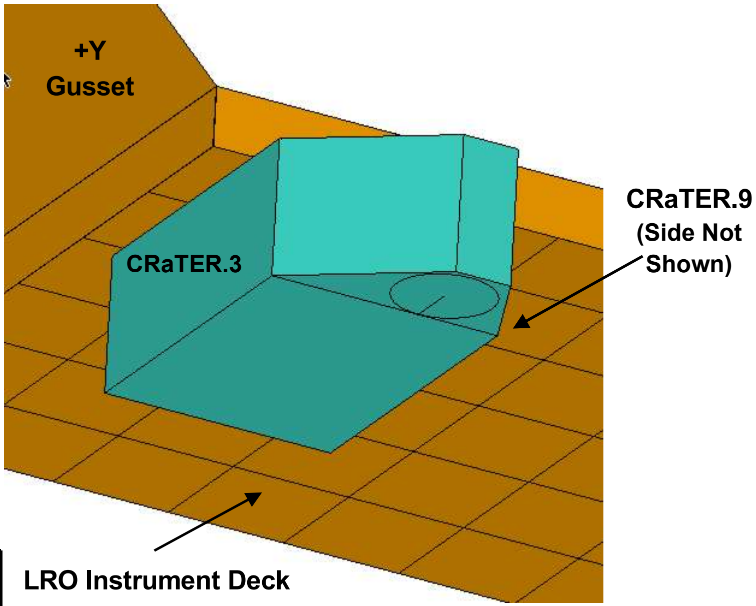
***Note: Heater nodes located on the LRO Instrument Deck maintain LOLA Main Housing I/F temperatures in the cold case.**

- LOLA Laser Housing will need operational and survival heater power – best done on housing
- Design/modeling is on going but has completed for a 1st go around
- Estimated steady-state heater power required on the LRO Instrument Deck is ~3 Watts (cold case)



Instrument Trends - CRaTER

- CRaTER may have changing temperature requirements
- A trade needs to be done between isolated versus conducted bench
- CRaTER will likely need operational and possibly survival heaters
- Design/modeling is very preliminary
- No steady-state heater power is required on the LRO Instrument Deck for the cold case with the current CRaTER model



	Hot Case (Beta 0°)		
Node	Transient Max	Steady-state	Transient Min
3	15.6	11.0	3.3
9	15.2	9.1	0.3
	Cold Case (Beta 90°)		
Node	Transient Max	Steady-state	Transient Min
3	-18.9	-18.9	-18.9
9	-18.9	-18.9	-18.9

Instrument Trends – LROC SCS

- SCS is moving onto a LROC plate isolated from the bench
- LROC will likely need operational and possibly survival heaters
- Design/modeling is very preliminary
- No steady-state heater power is required on the LRO Instrument Deck for the cold case with the current LROC/SCS model

Hot Case (Beta 0°)

Nod	Transient Max	Steady State	Transient Min
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
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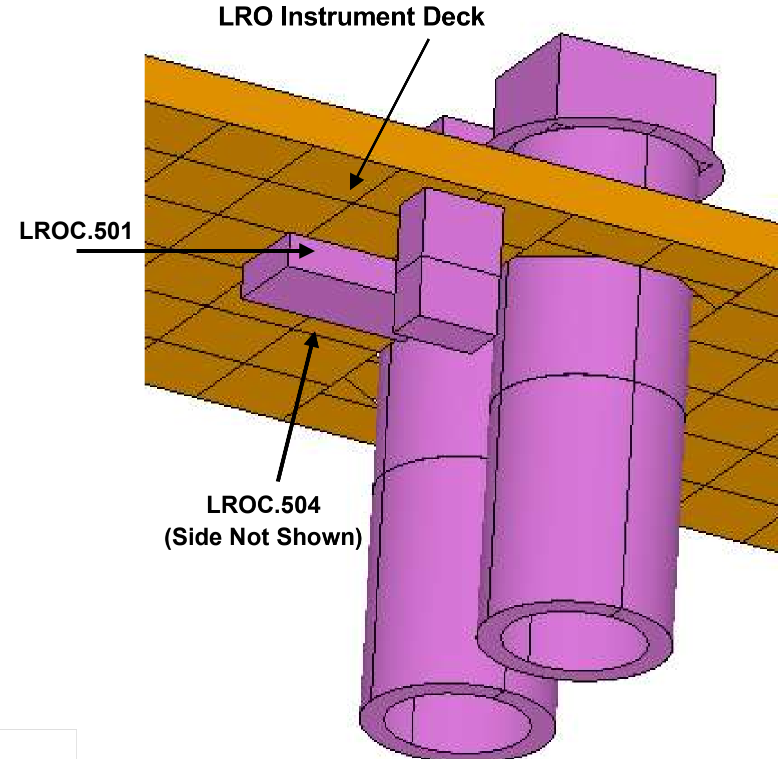
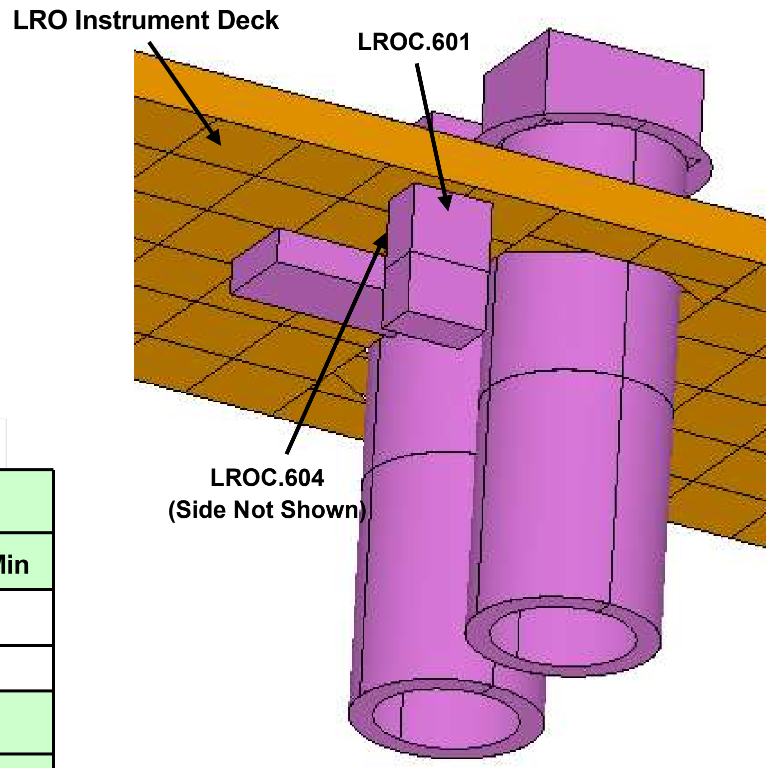


Instrument Trends – LROC/WAC

- WAC is moving onto an LROC plate isolated from the bench
- LROC will likely need operational and possibly survival heaters
- Design/modeling is very preliminary
- No steady-state heater power is required on the LRO Instrument Deck for the cold case with the current LROC/WAC model

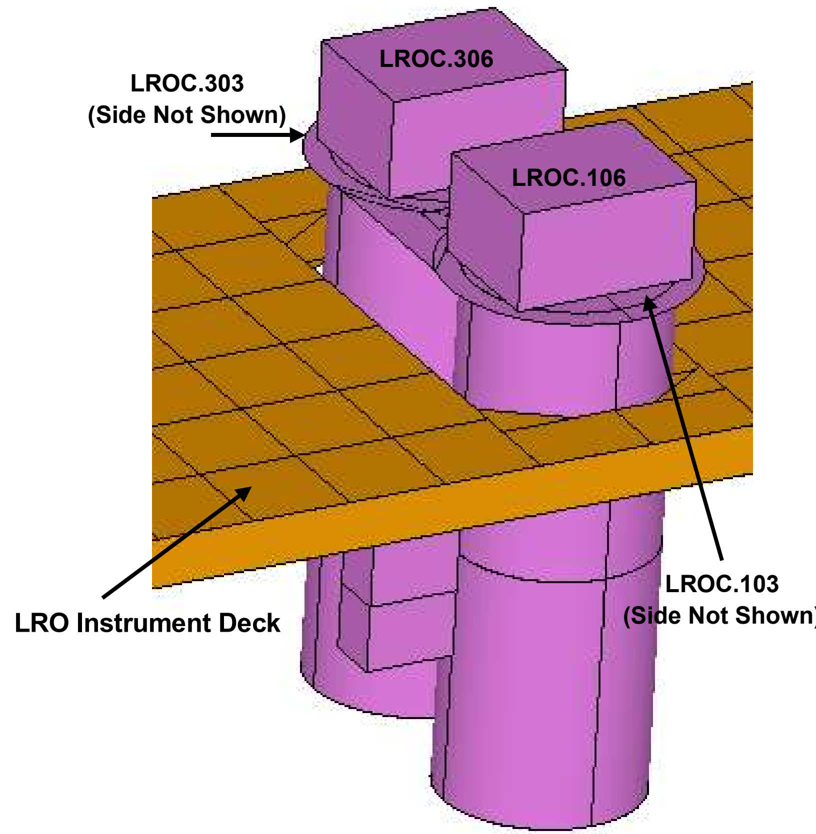


Node	Transient Max	Steady-state	Transient Min
	Hot Case (Beta 0°)		
601	26.3	7.5	-16.2
604	26.4	7.5	-16.2
	Cold Case (Beta 90°)		
Node	Transient Max	Steady-state	Transient Min
601	-25.8	-25.8	-25.8
604	-25.8	-25.8	-25.8

Instrument Trends – LROC NACs

- NAC 1 and 2 are moving onto a LROC plate isolated from the bench
- LROC will likely need operational and possibly survival heaters
- Design/modeling requires more updates
- No steady-state heater power is required on the LRO Instrument Deck for the cold case with the current LROC/NAC models

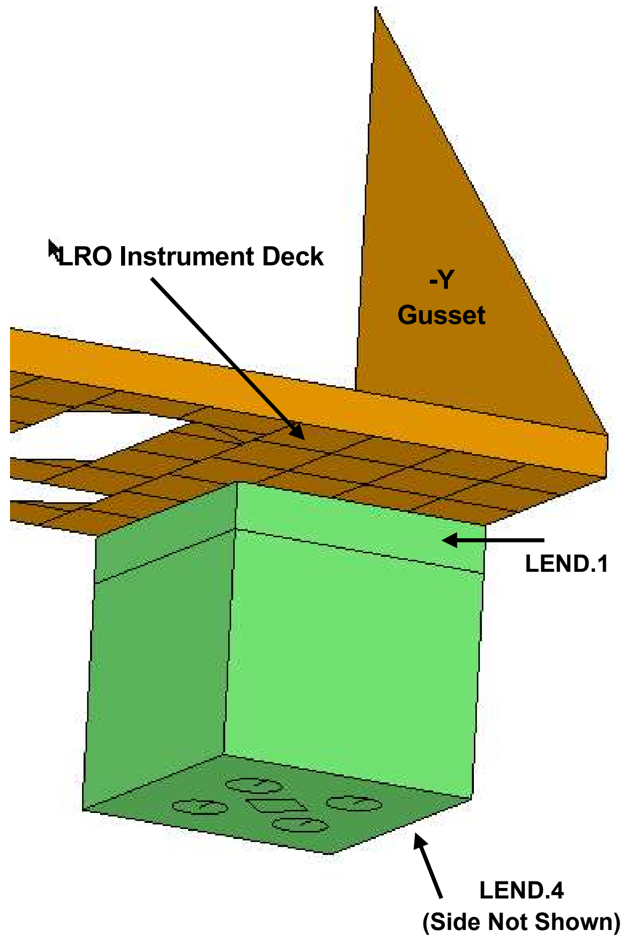
	Hot Case (Beta 0°)		
Node	Transient Max	Steady-state	Transient Min
103	40.4	37.8	32.8
106	38.7	33.7	27.3
303	32.3	30.2	26.8
306	29.8	26.0	21.6
	Cold Case (Beta 90°)		
Node	Transient Max	Steady-state	Transient Min
103	-29.9	-29.9	-29.9
106	-31.3	-31.3	-31.3
303	-29.9	-29.9	-29.9
306	-31.4	-31.4	-31.4



Instrument Trends - LEND

- A trade needs to be done between isolated versus conducted bench
- LEND should have survival heaters on the instrument not designed due to lack of modeling
- Design/modeling transfer to S/C has not been done
- We are very sensitive to the coupling of the detectors to the electronics to reduce orbital transience (assumed isolated detectors)
- Estimated steady-state heater power required on the LRO Instrument Deck is ~18 Watts (cold case)

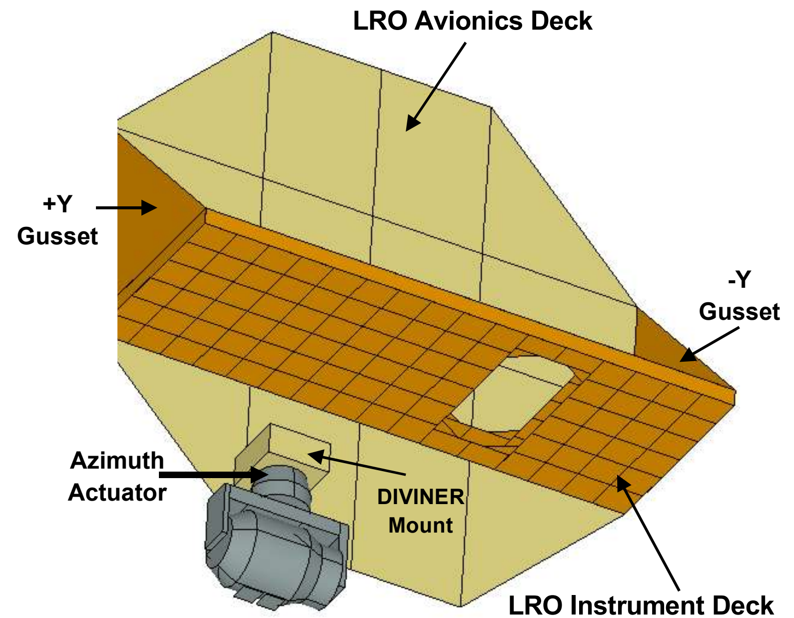
	Hot Case (Beta 0°)			**Heater Power**
Node	**Transient Max**	**Steady-state**	**Transient Min**	**(Watts)**
1	26.4	11.6	-8.3	
4	26.7	13.8	-4.7	0
	Cold Case (Beta 90°)			**Heater Power**
Node	**Transient Max**	**Steady-state**	**Transie nt Min**	**(Watts)**
1	-12.9	-12.9	-12.9	
4	-9.6	-9.6	-9.6	18*



***Note: Heater nodes located on the LRO Instrument Deck maintain LEND temperatures in the cold case.**

Instrument Trends - Diviner

- Need to get a better defined model of the instrument and the S/C mount.
- Diviner should have survival heaters on the instrument not designed due to lack of modeling
- Design/modeling transfer to S/C has not been done
- Concerned about nadir viewing and sun flux impingement
- Need a trade to explore moving electronics box to the zenith surface and whether to isolate from the instrument bus
- Estimated steady-state heater power required on the LRO Instrument Deck is ~35 Watts (cold case)
- Are there any details on the Electronics box?



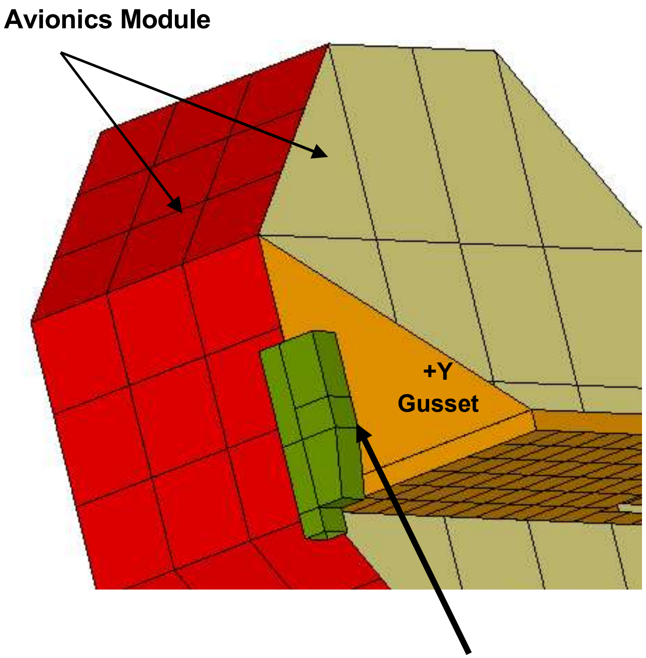
	Hot Case (Beta 0°)			Heater Power
Node	**Transient Max**	**Steady-state**	**Transient Min**	**(Watts)**
Actuato r	35.7	28.6	14.9	0
	Cold Case (Beta 90°)			**Heater Power**
Node	**Transient Max**	**Steady-state**	**Transient Min**	**(Watts)**
o r	-14.8	-14.8	-14.8	35.2 *

***Note: Heater nodes located on the LRO Instrument Deck maintain DIVINER Azimuth temperatures in the cold case.**

Instrument Trends - LAMP

- LAMP should have survival heaters on the instrument not designed due to lack of modeling
- Design/modeling transfer to S/C has been done
- Conductive coupling per mount 0.8 W/C
- Estimated steady-state heater power required on the LRO Instrument Deck is ~13 Watts (cold case)

	Hot Case (Beta 0°)			Heater Power
Node	Transient Max	Steady-state	Transient Min	(Watts)
4	21.0	13.3	2.9	0
15	27.2	18.8	7.8	
17	22.9	14.5	3.3	
	Cold Case (Beta 90°)			Heater Power
Node	Transient Max	Steady-state	Transient Min	(Watts)
4	-5.5	-5.5	-5.5	12.6
15	1.7	1.7	1.7	
17	-2.0	-2.0	-2.0	



***Note: Heater nodes located on the LRO Instrument Deck maintain LAMP temperatures in the cold case.**

Mission Modes Pointing

Early Orbit Operations: From Launch up until sun acq, we will be spinning about the thrust axis at a rate exceeding 0.1°/sec

Sun Acq/Safe Hold: -Y or –X axis is pointed at the sun within +/-15°

Lunar Transfer and Capture: Orbit maneuvers (<1 hour) may slew the instruments at a rate of 0.1°/sec through the sun and long term sun stay out area is 30° away from the +Z axis. Capture is at an orbit <200 km above the moon.

Nadir Science Orbit: Orbiter will be pointing nadir according to pointing requirements. Orbit is 50 +/-20 km.

Off-Nadir Pointing: We can off point for 15 minutes (TBR) total including the slew there and back for a maximum of 20° off nadir. Thermally we will not allow the 20° off point to allow any greater sun angle into the instrument apertures than in the worst case for the mission currently 16°. Off pointing can only be done at most once every other orbit.

Temperature Requirements at Thermal Interface

LRO MASTER	13-Apr-05 7:00 AM		
EQUIPMENT LIST		Op Range	Surv Range
Subsystem	Components	°C	°C
CRaTER	INST #1		
	Instrument Pkg.#1	-30 to +35	-40 to +50
	Instrument Elect. #1	-30 to +35	-40 to +50
Diviner	INST #2		
	Instrument Pkg.#2	-20 to +50	-70 to +80
	Instrument Elect. #2	-20 to +50	-70 to +80
LAMP	INST #3		
	Instrument Pkg.#3	-10 to +40	-20 to +40
	Instrument Elect. #3	-10 to +40	-20 to +40
LEND	INST #4		
	Instrument Pkg.#4	-20 to +50	-40 to +70
	Instrument Elect. #4	-20 to +50	-40 to +70
LOLA	INST #5		
	Optics Package	+0 to +30	-20 to +40
	Instrument Electronics	-10 to 40	-20 to +50
LROC	INST #6		
	NAC (2)	-35 to +30	TBD to +60
	WAC	-35 to +30	TBD to +60
	SCS	-35 to +60	-55 to +60

Thermistor Allocations (S/C monitored)

Instrument	Number of Telemetry pts
CRaTER	2
Diviner	4
LAMP	2
LEND	2
LOLA	4
LROC	8

- S/C thermistors will be the only ones that can be monitored during periods when the instrument is off
- Instrument Teams shall pick locations for telemetry that allow them to evaluate the health and safety of the instrument during periods when the instrument is turned off
- Allocations on this chart represent a maximum number and may be reduced by the instrument teams

S/C Heater Circuits

Instrument Operation Heater Power Description: This switch is intended to service operational heaters in the instrument module that can be on the bench or on instruments. The sizing of the heaters will be designed such that all instrument interfaces are maintained thermostatically at the cold end of the operational temperature range regardless of the actual power that the instrument is dissipating. In the cold case, this heater power may be close to the orbit average power dissipation of the instrument plus any additional power that is necessary to offset the losses from the instrument to the environment. In the hotter Beta angles, this heater power will be reduced. Heater control will be thermostatic located on or near the component/instrument.

Instrument Survival Heaters Description: This service will primarily service the instruments and instrument module to maintain all the instruments above their cold survival temperature. These heater circuits may be on the instruments or instrument optical bench. Heater control will be thermostatic located on or near the component/instrument.

LROC Decontamination Heaters Description: This service will primarily service the LROC Decontamination Heaters. These need to be sized per the lunar environment and may be one or many switches. Heater control will be thermostatic located on or near the component/instrument.

Heaters shall be sized at 24 V (TBR) with a maximum 70% duty cycle during test

S/C powered heater circuits (uncontrolled but wired to S/C)

Instrument	Op Htr @ 24 V (W)	DeContam Htr @ 24 V (W)	Surv Htr @ 24 V (W)
CRaTER	None	None	None TBR
Diviner (Elec Box)	TBD	None	TBD
Diviner (Detector)	Supplemental Htr	None	7.3 TBR General 0.0 TBR AZ Motor
LROC NAC1	TBD	50 TBR	6 TBD
LROC NAC2	TBD	50 TBR	6 TBD
LROC WAC	TBD	10 TBR	5 TBD
LROC SCS	TBD	TBD	5 TBD
LAMP	TBD	None	None TBR
LEND	TBD	None	6 TBR
LOLA Elec	TBD	None	TBD
LOLA Op Bench/Laser	None	None	TBD
Total	TBD	110 TBR	TBD

Instrument controlled variable heat sources

Instrument Controlled Operational Heaters: These heaters will receive power from the main instrument power source that is powered when the instrument is turned on and will be controlled however the instrument chooses to control it. Details need to be known at the S/C level for thermal analysis and shall show up in the thermal models.

Instrument Decontamination Heaters Description: These heaters will receive power from the main instrument power source that is powered when the instrument is turned on and will be controlled however the instrument chooses to control it. In general these heater will only be turned on for short durations. Details need to be known at the S/C level for thermal analysis and shall show up in the thermal models.

Instrument TECs, etc.: Heat sources that are temperature variant such as Thermal Electric Coolers shall be powered from the main instrument power source that is powered when the instrument is turned on and will be controlled however the instrument chooses to control it. The power dissipated ranges from a minimum to a maximum based on the interface temperature and other thermal conditions. Details need to be known at the S/C level for thermal analysis and shall show up in the thermal models.

Internal power provided by instruments

Instrument	Op Htr @ 24 V (W)	DeContam Htr @ 24 V (W)
CRaTER	TBD	None
Diviner	TBD	None
LROC NAC1	TBD	None
LROC NAC2	TBD	None
LROC WAC	TBD	None
LROC SCS	TBD	None
LAMP	None	2 W TBR
LEND	None	None
LOLA Elec	10 TBR	None
LOLA Op Bench/Laser	15 TBR	None
LOLA TEC	0-3 TBR	None
Total	TBD	TBD

Other Temperature Requirements

- Temporal Gradient Requirements
  - LROC dT < ~20°C over an orbit (Can not address without proper models)
  - LEND dT < ~10°C over an orbit (Can not address without proper models)
  - LOLA TBD
- Temperature Rate of Change: TBD °C/min
- Spatial Gradient Requirements
  - TBD between mounting feet

Telemetry Temperature Limits

- ***Hard Limits***: The absolute minimum and maximum temperatures that may be experienced without inflicting damage or permanent performance degradation.
- ***Qualification Temperature Limits***: The minimum and maximum temperatures that are exactly 10°C wider than the flight predict limits, over which, the responsible hardware manager guarantees that the hardware will operate or survive over the mission lifetime. This will be confirmed by testing that induces the limits stated. The ±10°C is to provide margin for modeling/analysis inaccuracies and manufacturing variations and to help compensate for the less than lifetime thermal cycling performed before launch. The responsible hardware manager shall induce the qualification temperature limits in thermal vacuum testing prior to delivery to verify that the hardware can operate and survive over the entire specified temperature range.
- ***Flight Design Limits***: The minimum and maximum temperatures bounding the temperature range over which the CBE limits, might vary. While the CBE limits might vary with design updates, the flight predict limits are treated as an "allocation" in the sense that the responsible hardware manager commits to not exceed them by design. The flight design limits must be at least 10°C inside the hard limits in order to qualify the component.
- ***Current Best Estimate (CBE) Limits***: The CBE of the expected minimum and maximum temperatures based on testing and/or analyses using the S/C conduction and radiation boundary conditions provided. Any model or test result typically has 5-10°C of uncertainty added to it to address modeling technique compromises and systemic uncertainties. Uncertain decreases with increased testing and modeling fidelity typically by decreasing the uncertainty from 10°C to 5°C in all CBEs.

Upcoming Milestones

- May 1st – Receive Instrument Reduced Thermal Models
  - Models need to be follow the requirements document (Pick up a copy of **Lunar Reconnaissance Orbiter (LRO) Thermal Math Model Requirements)**
  - Reduced thermal models will include an adequate level of detail to predict under worst hot, cold, and safe-hold conditions all critical temperatures including those driving operational and survival limits and heater power requirements
- Early June – Provide reduced spacecraft model to instruments (based on May 1st model deliveries)

Thermal Issues to Consider

- All Instruments need Survival Heater and Operational Heaters sized for the lunar environment
- Optical bench interface temperature requirements in the relevant locations need to be widen or eliminated to reflect new operational and survival heater locations
- Delivery of the Instrument Thermal Models by May 1st is driving System to Instrument thermal distortion and reduced S/C model delivery
- Model deliveries shall be in accordance with model requirements document
- Instrument thermal design, analysis, and I&T shall be in accordance with the specific instrument ICDs and general thermal specification
- All external coatings must be grounded in accordance with the Electrical Systems Interface Control Document (ICD)
- instrument power dissipation modes/profile need to be provided