Simulating the Lunar Thermal Environment for the Surface-Deployed LEMS Artemis III TVAC Test

Ethan Burbridge[1]
Vertex Aerospace, LLC, Grasonville, MD 21638

Juan Rodriguez-Ruiz[2]
NASA Goddard Space Flight Center, Greenbelt, MD, 20771

and

Daniel Powers[3]
NASA Goddard Space Flight Center, Greenbelt, MD, 20771

The Lunar Environment Monitoring Station (LEMS) is an autonomous, survive-the-lunar-night seismic suite to be deployed on the lunar surface by the Artemis III crew and designed to operate continuously for two years. It will see the extremes of the lunar south pole thermal environment where surface temperatures range from -200°C to +20°C and where nighttime duration is at least 354 hours. Given power and mass constraints, the thermal system is limited to 2.5 Watts of heat during the lunar night. Presented is the system thermal vacuum test plan and configuration to validate the thermal control system performance in a flight-like environment. The test will measure the nighttime heat leaks for the bus and seismometers to ensure lunar night survival and operability.

Acronyms and Nomenclature

BB	=	Broad Band
C&DH	=	Command and Data Handling
DSN	=	Deep Space Network
E_b	=	batter capacity of the LEMS-A3 bus at -30°C or 940.8 Wh
E_{LEMS}	=	Energy measurement based on the LEMS flight unit power supply
E_{htr}	=	measured heater power of the GSE bus heater over a nominal lunar night
E_{0Q}	=	thermal energy flow through the GSE bus harnessing
ΔE_{SP}	=	delta of energy consumed by the SP seismometer RRU compared to the flight unit
ΔE_{BB}	=	delta of energy consumed by the BB seismometer RRU compared to the flight unit
ΔE_{env}	=	additional heat loss expected due to the difference in environment from TVAC to flight
EPS	=	Electrical Power System
GN2	=	Gaseous Nitrogen
GSE	=	Ground Support Equipment
GTP	=	Ground Test Panel
HMS	=	Hibernation Management System
IMLI	=	Integrated Multi-Layer Insulation
LEMS-A3	=	Lunar Environment Monitoring Station – Artemis 3
LN2	=	Liquid Nitrogen
LPT	=	Limited Performance Test
n	=	number of measurement samples with substantially equal time periods
PF	=	Protoflight

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[1] Thermal Engineer, Vertex Aerospace, LLC, and PO BOX 192, Grasonville, MD 21638
[2] Thermal Principal Design Lead, Thermal Engineering Branch, and 8800 Greenbelt Rd Greenbelt, MD 20771
[3] Thermal Engineer, Thermal Engineering Branch, and 8800 Greenbelt Rd Greenbelt, MD 20771

PI = Proportional, Integral
PRT = Platinum Resistance Thermometer
RRU = Risk Reduction Unit
SAPP = Signal and Power Passthrough
SLI = Single Layer Insulation
SP = Short Period
T_1 = temperature at the 0Q heater
T_2 = temperature at the GTP
t_{night} = nominal length of lunar night per LEMS-A3 requirements at 360 hours
VDA = Vapor Deposited Aluminum
σ = systematic error of the measurements
ϵ = random error of the measurements
$0Q$ = zero heat flow

I. Introduction

THE Lunar Environment Monitoring Station for Artemis III (LEMS-A3) is an autonomous remote seismic monitoring station to be deployed on the south pole region of the Moon by the crew. The seismic suite consists of two three-axis sondes that will be buried in the lunar regolith to detect seismic events which consist of shallow moonquakes, deep moonquakes, meteoroid impacts, and thermal cycling. LEMS-A3 will be gathering the first seismic data for the region which will inform objectives and requirements for future lunar south pole missions.

LEMS-A3 includes all systems necessary for remote operation like direct-to-earth communications, solar power generation, battery storage, command and data handling, and thermal control. Figure 1 details the system architecture. Novel to this system is a low-power Hibernation Mode which disables all systems like communications and data processing not related to science gathering or system telemetry. LEMS-A3 will operate in this Hibernation Mode 98.6% of the mission to conserve power. The Hibernation Mode is controlled via the Hibernation Management System (HMS) which nominally operates continuously over the two-year mission. Once every 24 hours, for 20 minutes, HMS will enable the Command and Data Handling (C&DH) card which maintains the operations schedule based on timekeeping in the HMS. During this 20-minute "Awake" period, the C&DH will determine the charge state of the battery and the solar power incident on the solar arrays based on the two sun sensors and enable or disable the Electrical Power System (EPS) as appropriate. Figure 2 pictures the concept of operations which includes at least one monthly, three-hour, direct-to-Earth communications window using the Deep Space Network (DSN) for downloading science data and system telemetry.

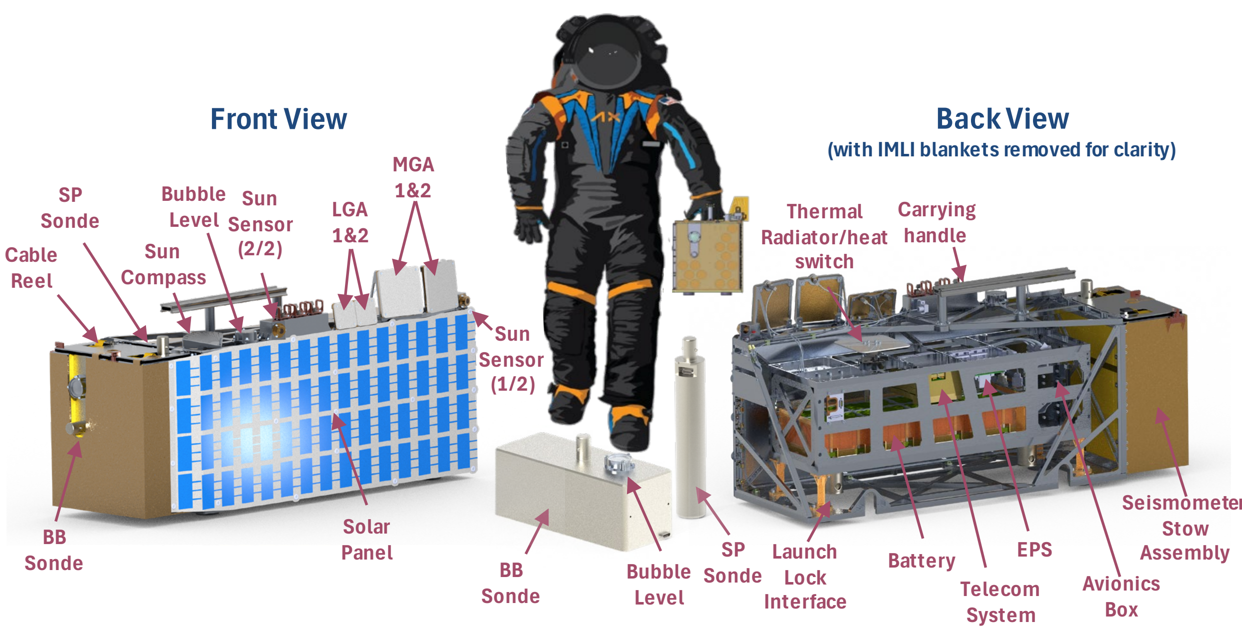


Figure 1: LEMS-A3 Components

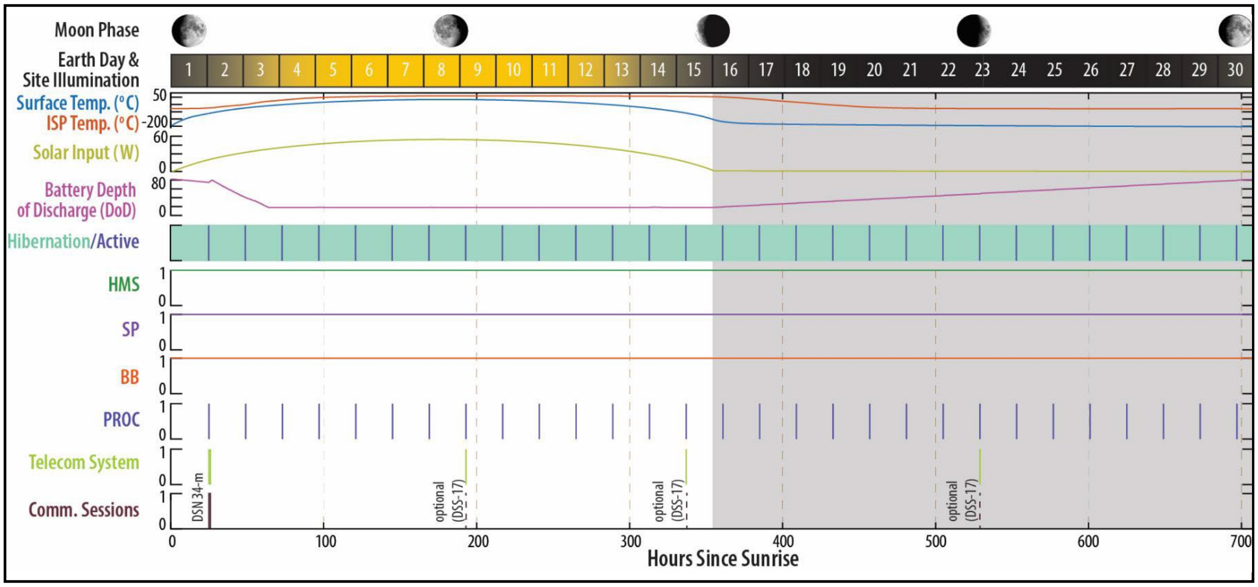


Figure 2: LEMS-A3 Concept of Operations

This paper is an exposition of the LEMS flight unit system-level TVAC test plan and configuration to meet flight qualification test objectives. The configuration enables testing to qualification temperature extremes and also simulates the lunar thermal environment. This paper will expand upon methods to expedite the test temperature transitions using a partial GN2 backfill, and the method for establishing thermal balance stability criteria and to demonstrate that LEMS is able to survive the lunar night. It presents thermal test predictions for hot/cold plateaus and thermal balance cases, but not the as-run test results.

II. Thermal Architecture

Once LEMS is deployed for operations on lunar south pole, it is divided into three thermal regions:

1. The superstructure, which is in contact with the lunar surface and with elements directly exposed to the extreme hot and cold lunar environments.
2. The bus structure, which contains components that require tighter temperature control such as electronics and battery, and is thermally isolated from the superstructure and the lunar environment.
3. The seismometers, which are buried below the lunar surface.

Figure 3 below shows CAD images with and without the Integrated Multi-Layer Insulation (IMLI) to show the distinction between the superstructure and the bus structure. Figure 4 shows how the bus structure is thermally isolated from the superstructure and the external environment [1].

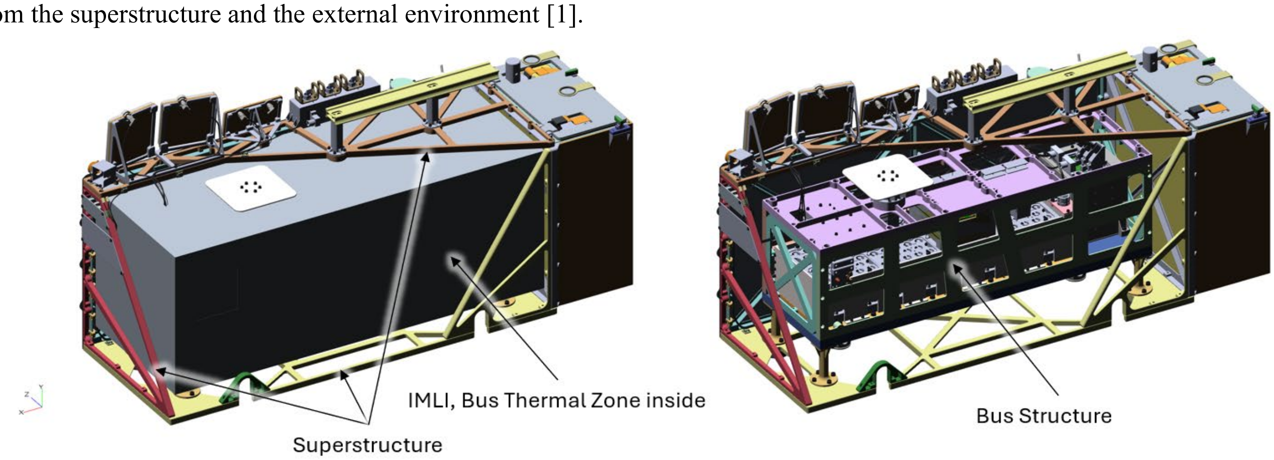


Figure 3: LEMS Bus Structure and Superstructure

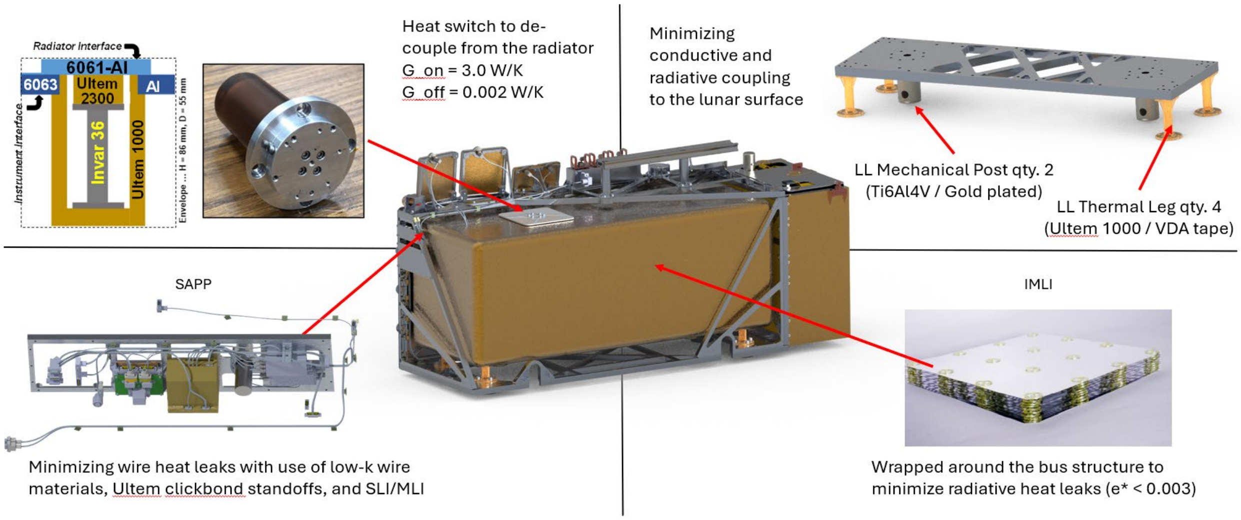


Figure 4: Bus Thermal Isolation Design

III. South Pole Lunar Thermal Environment

Current candidate landing locations for Artemis III include lunar latitudes between -83.6° and -88.2°. At these latitudes daytime solar angles are shallow at around 10°, and surface temperatures range from +20°C during the warmest part of the lunar day, and -200°C during the lunar night. Figure 5 below shows thermal environment conditions for our hot lunar day and cold lunar night balance case. Detailed assumptions on the LEMS lunar thermal environment are detailed in E. Burbridge, J. Rodriguez-Ruiz [1].

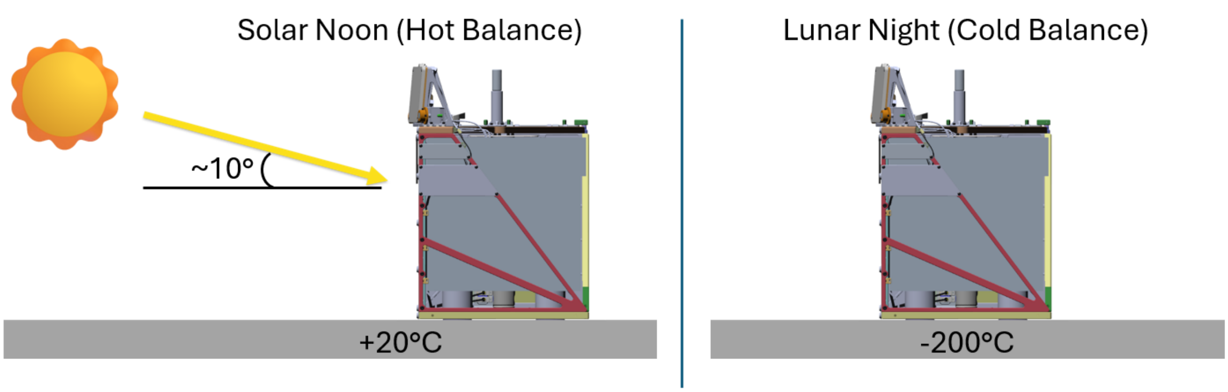


Figure 5: Thermal Environment Boundary Conditions for Hot and Cold Balance

A detailed thermal model was developed for LEMS and Figure 6 shows the temperature contour map of the lunar surface around LEMS at noon time and during the lunar night. Surface temperature variations due to localized reflection and shadowing effects can be appreciated in these contour maps. The IMLI is hidden to show the internal component temperatures. The thermal model was used to simulate how LEMS thermally responds over the course of a full lunar day/night cycle, also called a lunation, which is approximately 29.5 Earth days in duration. On Figure 7, the left image shows the thermal response of components mounted internally on the bus structure and the right image for components mounted externally on the superstructure. The figure also shows the sharp temperature rise at 16:00 due to the high power 3hr comms session. The change in slope at 19:00 is due to the heat switch opening around 0°C, thereby reducing the cool down rate by reducing heat leaks during the lunar night, which is a key design feature to survive the full lunar night.

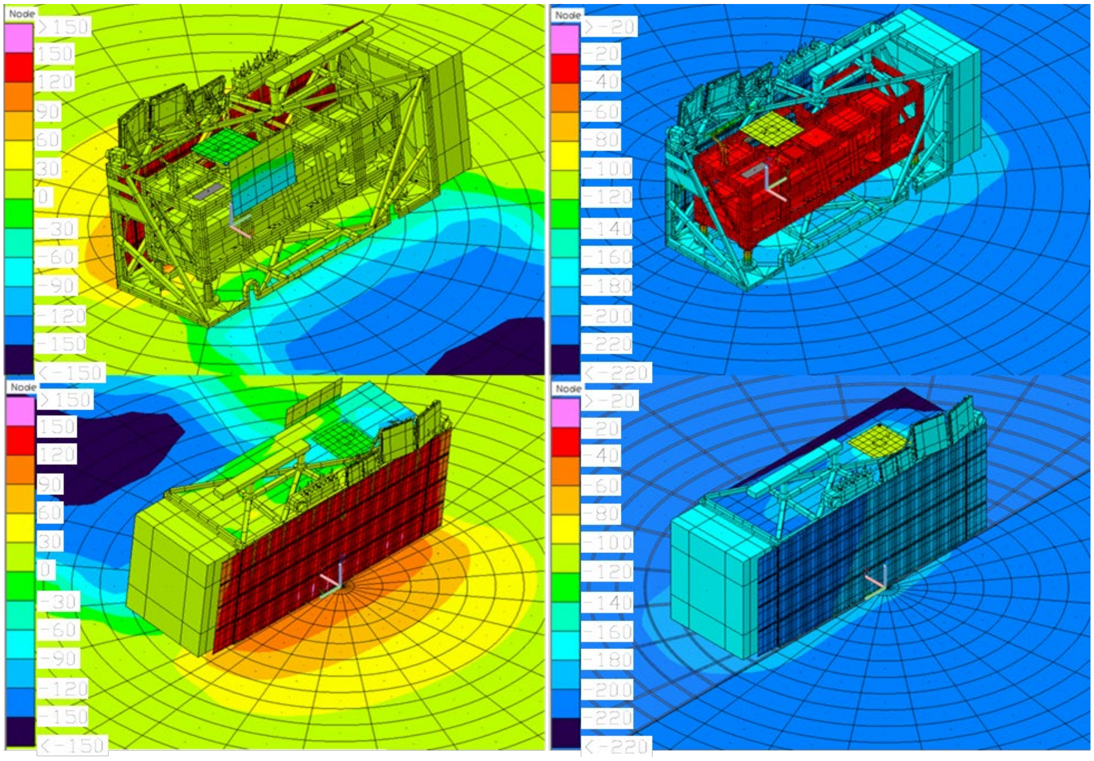


Figure 6: (left) Hot Op temperature map at solar noon with 5° inclination.
(right) Cold Op temperature map during the lunar night.

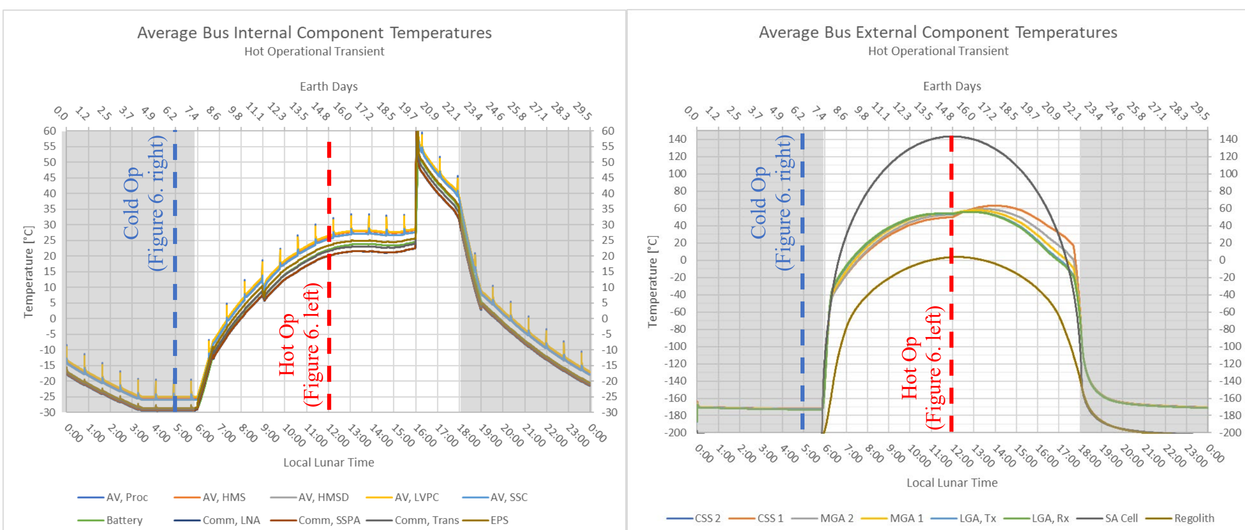


Figure 7: Bus (left) and Superstructure (right) Component Temperatures over a Lunation

IV. TVAC Test Plan and Configuration

A. Test Setup

LEMS will undergo a system-level thermal vacuum test at NASA Goddard Space Flight Center to qualify it for spaceflight. The lunar thermal environment will be simulated with a variety of high emissivity panels which are cooled with GN2/LN2 flow, and heated with a variety of heaters installed to achieve desired warm temperatures. For the radiator and solar array cryopanels, Z307 black coated open-cell honeycomb panels were used. This is done to obtain a consistently high emissivity of about 0.98 and increase the sink's heat transfer effectiveness [2]. Figure 8 shows the CAD image of our TVAC configuration, Figure 9 shows a photograph of LEMS during setup inside the TVAC chamber, and Figure 10 shows the TVAC test block diagram which is a schematic showing how the thermal test panels are interfacing with LEMS flight components.

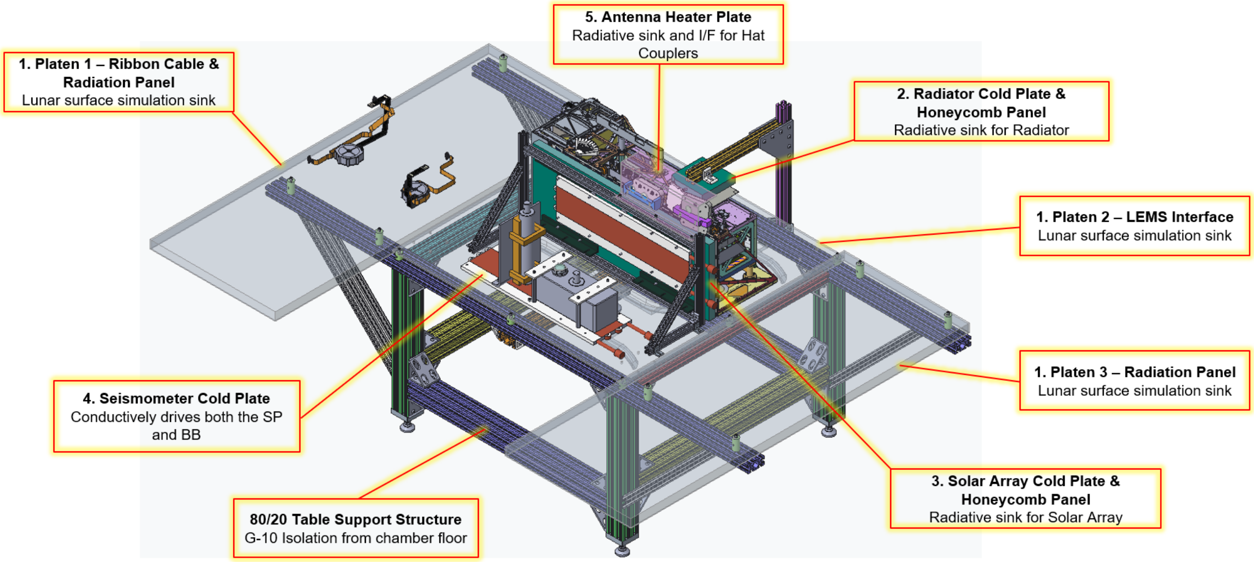


Figure 8: TVAC Test Configuration

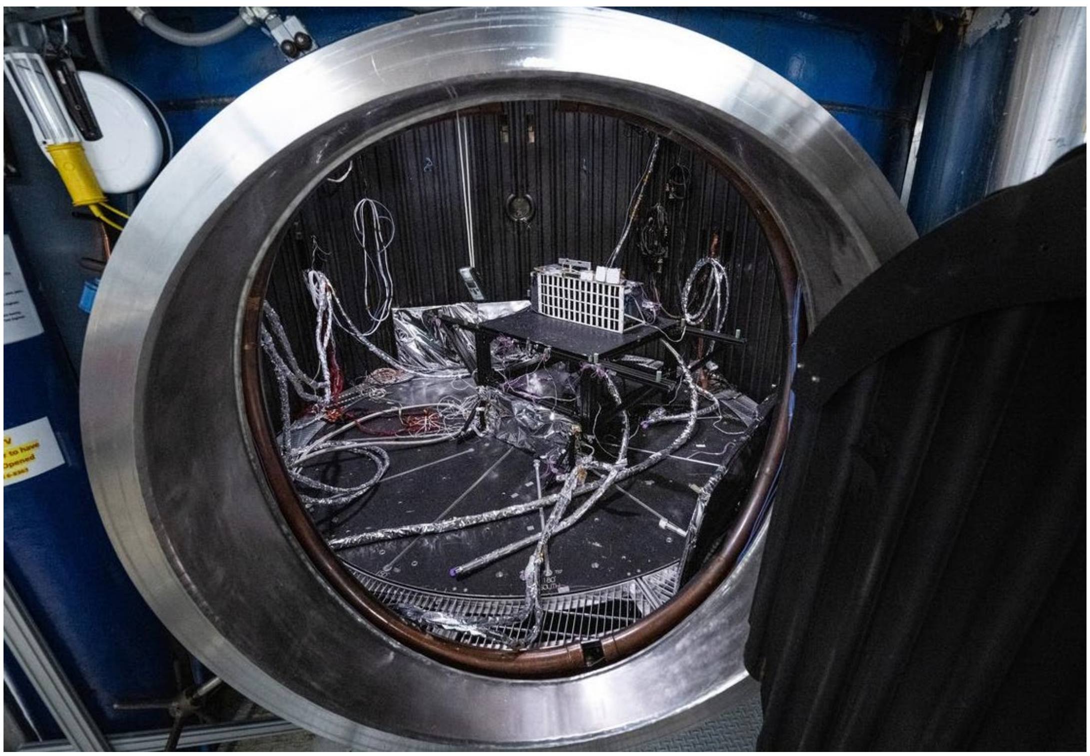


Figure 9: LEMS During Setup For TVAC Test

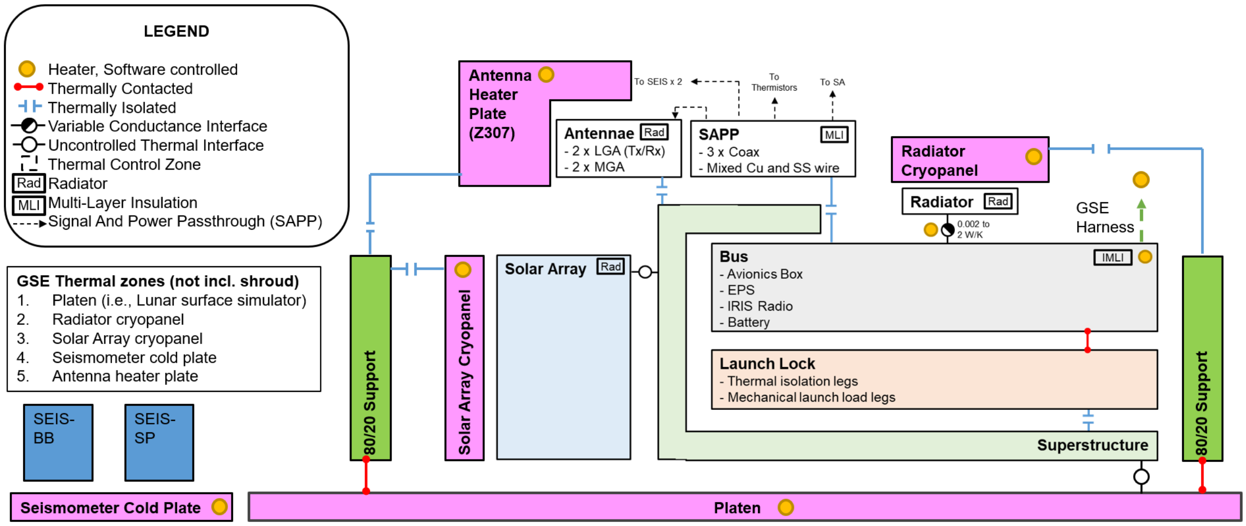
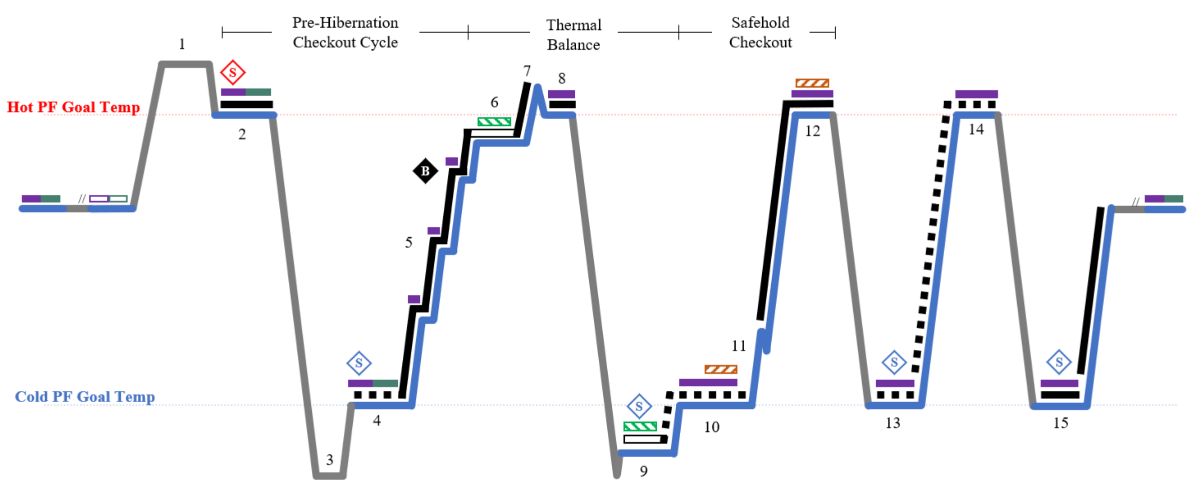


Figure 10: TVAC Thermal Block Diagram

B. Test Profile and Objectives

With the test configuration shown, the goals of the system-level TVAC test can be accomplished, which includes simulating the flight-like environments for the hot and cold balance cases, demonstrating hardware thermal capacitance to absorb the 3hr comms session power spike, and achieving protoflight temperatures for the different plateaus. Figure 11 shows the test profile along with a list of the major plateaus and objectives accomplished.



	Hot or Cold Start
	LEMS-A3 Powered
	Unpowered, GN2 Backfill
	CPT / LPT on Power Supply
	CPT / LPT on Battery
	Thermal Balance
	Safehold Checkout
	Max Voltage Config. (33.6 V)
	Nom Voltage Config. (28.0 V)
	Min Voltage Config. (25.4 V)
	Battery Charging
//	Pump down / Repress

Step	Description
1	Bakeout
2	Hot Op Plateau 1
3	Cold Survival
4	Cold Op Plateau 1
5	Awake/Hibernation Cycle Test (Day-In-The-Life)
6	Hot Balance (solar noon)
7	Monthly Comms (3hr high power transient)
8	Hot Op Plateau 2

Step	Description
9	Cold Balance (lunar night)
10	Cold Op Plateau 2
11	Monthly Comms (3hr high power transient)
12	Hot Op Plateau 3
13	Cold Op Plateau 3
14	Hot Op Plateau 4
15	Cold Op Plateau 4

Figure 11: TVAC Test Profile

C. Methods to Expedite the Test

LEMS is designed to keep the bus structure thermally isolated from the lunar environment. This requirement is driven by the need to survive on battery power alone for approximately 15 Earth days in the cold lunar night environment without any energy source such as solar or nuclear power. The system heat leak is about 1.5 W, which represents a very low heat transfer to mass ratio, and therefore an extremely slow temperature cooling rate. Based on preliminary analysis, as can be appreciated in Figure 12, this results in over a week to cool the internal bus components from a warm operating temperature of 50°C down to -30°C, which is schedule and cost prohibitive.

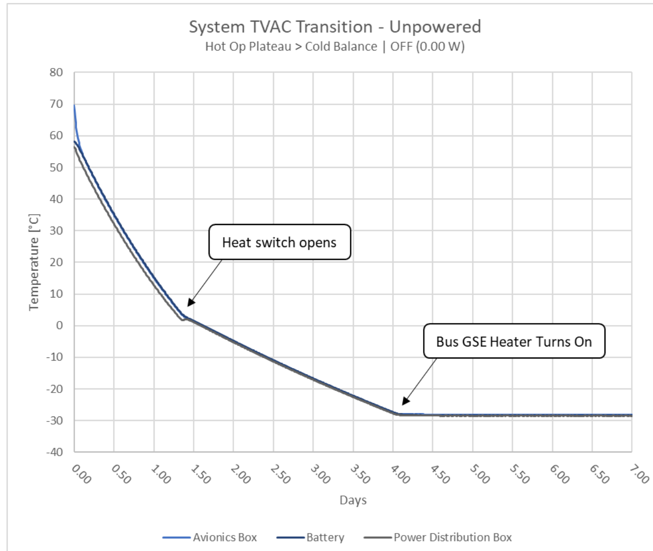


Figure 12: Temperature transition estimates in a high-vacuum environment

To accelerate the hot to cold transitions, a technique is used where the TVAC chamber is partially backfilled with enough cold GN2 to short the IMLI [2] and introduce some gas conduction to help cool down the test article. For this accelerated transition the flight hardware is powered off to accelerate the cooling effect and to avoid the risk of any electronic damage due to arcing when crossing the corona pressure region. A test Kapton film heater was installed on the bus structure to keep the flight hardware from going below cold temperature limits during these transitions. The bus GSE heater also facilitates over-driving the transitions during the unpowered cool downs and shortens the long thermal balance asymptote by catching the hardware at a lower temperature with this heater. Subsequently LEMS would power up and the heater setpoints would be raised up using PI controls.

This technique was tested in January 2026 during the TVAC checkout test. The TVAC checkout test included all of the TVAC GSE hardware shown in the previous section plus the LEMS TRL-6 development unit, which had a similarly built IMLI covering the bus structure. The effectiveness of the partial GN_2 backfill was assessed by measuring both the heater power to hold temperature and the cooldown rate of the mass within the IMLI at various chamber pressure levels. Figure 13 plots the heater power vs. pressure to hold the test article at -20°C with diminishing returns in improvements above 13 pa (0.1 torr). Figure 14 shows the cool down rate over the course of 1 hr and shows dramatic improvements when using this technique to accelerate hot to cold transitions during TVAC. Based on the results from this test, a pressure range 40 and 66 pa (0.3 and 0.5 torr) was chosen for the system TVAC test.

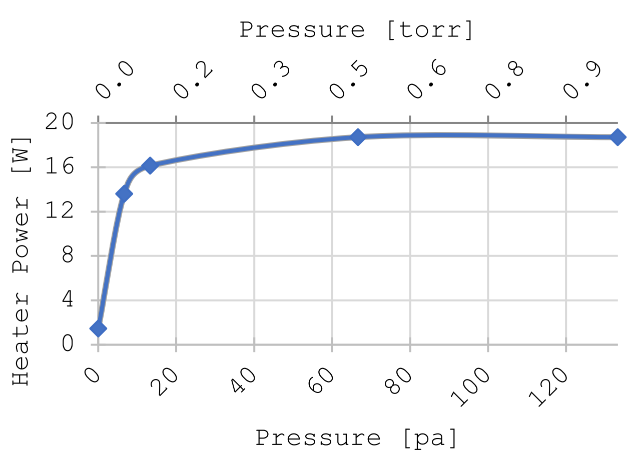


Figure 13: Heater Power vs. GN2 backfill pressure

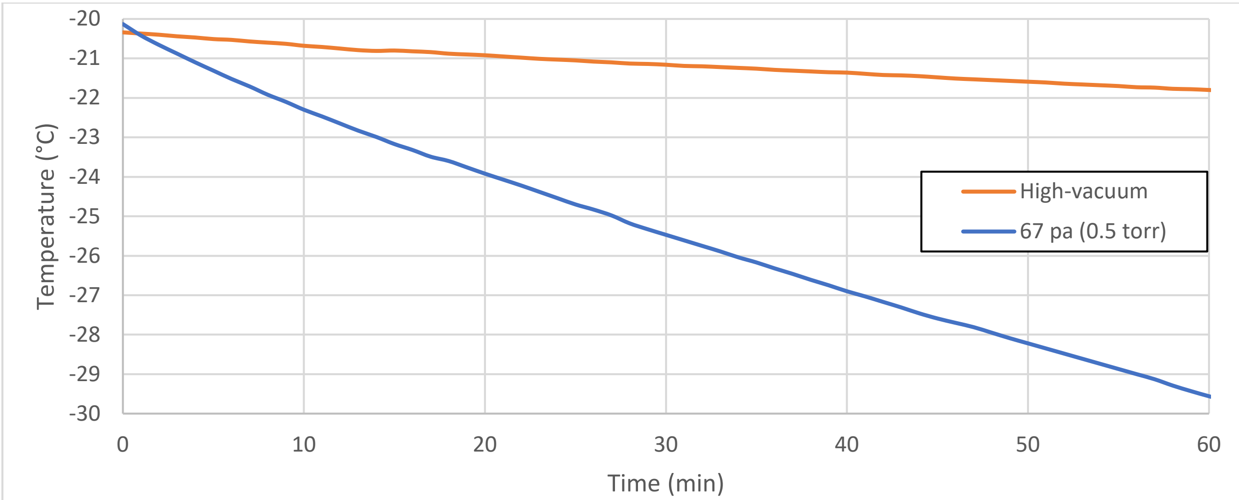


Figure 14: Temperature drop vs. time for high-vacuum and 67 pa (0.5 torr) pressure

D. Test GSE for Thermal Stability

Figure 15 lays out the test GSE used to measure heat flows during thermal balance. The test is configured to minimize and measure non-flight heat losses to ensure accurate measurements of heat flows for nighttime energy consumption predictions. The elements of this GSE are the bus GSE heater, and the Ground Test Panel (GTP) Zero-Q (0Q) heater.

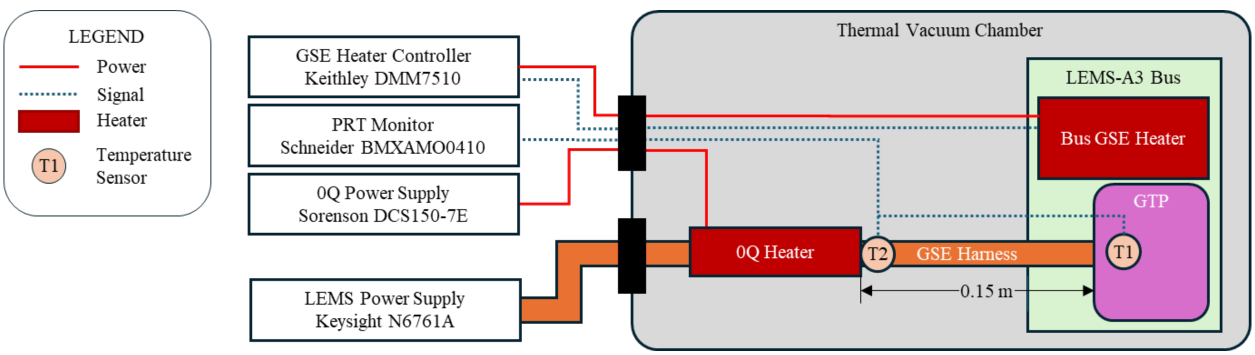


Figure 15: Thermal Balance Ground Support Equipment

The flight hardware, including the Short Period (SP) and Broad Band (BB) seismometers is powered via an external power supply during thermal balances. The Keysight N6761A power supply was selected for its accurate supply and measurement capabilities. The LEMS-A3 bus will be configured into hibernation mode for the cold balance. The seismometer environment will be set so that the internal heater will not cycle and the only power consumption in the SP and BB seismometers are the electronics in standby.

The bus GSE heater is installed onto the bus structure and is PI controlled by a Lakeshore 336 to reduce signal noise during the balance measurements. A Keithly DMM7510 monitors the power supplied to the GSE heater. The flight Bus Op heater is intentionally turned off during the cold balance since it lacks PI control and would limit the ability to accurately determine the system's power levels to maintain stability and determine whether LEMS is able to survive the lunar night.

The 0Q heater is a Kapton film heater wrapped around the electrical GSE wire bundle, also called the GSE harness, which is used to power and control the LEMS-A3 flight hardware during testing. Because the GSE harnessing is not present in flight, the 0Q heater adjusts the temperature of T2 until it matches T1 to minimize heat loss. Four-wire Platinum Resistance Thermometers (PRTs) were chosen for T1 and T2 to reduce uncertainty in the temperature measurements and gradient. Additionally, silicon diodes were mounted in the same locations to verify the readings.

V. TVAC Analysis Predictions

A. Thermal Balance Stability Criteria Methodology

Given the long lunar night (>360 hours) and TVAC schedule limitations for cold balance (48 hours), a thermal stability methodology was developed to validate lunar night survivability. Cold operational thermal balance is completed when the predicted nighttime thermal energy loss is less than the LEMS battery capacity at -30°C. The sources of energy loss are detailed in Eq. (1):

$$E_b \geq E_{LEMS} + E_{htr} + E_{0Q} + \Delta E_{SP} + \Delta E_{BB} + \Delta E_{env} + \sum 3\sqrt{\sigma^2 + \epsilon^2} \tag{1}$$

The measured data for each source of energy consumption is power, so predictor tools were made to extrapolate the measured power to total nighttime energy. For E_{LEMS} and E_{0Q}, a simple linear regression is sufficient given that those terms reach stability quickly. E_{LEMS}, as the power supply for LEMS during TVAC, is independent of small temperature changes and should be constant during cold balance. E_{0Q} should be zero during the test but uncertainty in the readings of the temperature sensors can result in a small temperature gradient that is calculated from the conductance of the harnessing attached to the GTP.

ΔE_{SP} and ΔE_{BB} are the difference in energy consumption between the seismometer Risk Reduction Units (RRUs) used in the System TVAC and the flight units being tested separately due to schedule constraints. In System TVAC, the seismometers are powered by the power supply referenced by E_{LEMS}. The deltas correct for the differences.

E_{htr} is expected to require a non-linear regression due to the long thermal constant of the LEMS-A3 bus and potential errors in the PI gains for the bus GSE heater. Different regression types such as a decaying exponential or least squares fit will be used. Fitness will be evaluated using similar methods to the linear regressions. Additionally, test results will be compared to predictions made by the Thermal Desktop model of the bus.

Because the test results will be used to extrapolate several times longer than the sample period, an accounting of the measurement errors was done to ensure the test would validate lunar night survivability with a confidence of at least three standard deviations. For each energy loss measurement, the error sources are categorized as systematic or random. The systematic errors are derived from errors in measuring equipment often reported by the manufacturer as a three standard deviation value. Systematic error bounds are applied to each measurement and are summed over time, rather than a root sum of the squares, for conservatism. Random errors are signal noise inherent to the measurement and are propagated via the regression statistics. The systematic and random errors are combined via quadrature for the final error bounds. Figure 16 shows the flow of a measurement to prediction.

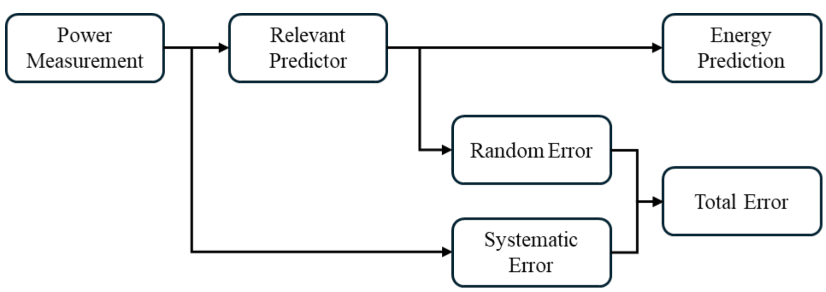


Figure 16: Measurement Prediction and Error Propagation for One Term of Eq. (3)

There are two types of systematic errors: power and geometric. Power errors are the result of errors in the power supplies and monitors controlling those circuits. Table 1 details the power supplies used in the test and their errors. Eq. (2) is the method for calculating nighttime energy consumption for power supplies that are expected to be stable. Eq. (3) is the method for propagating the systematic error for the 0Q heater.

$$E_{LEMS} = t_{night} IV \tag{2}$$

$$\sigma_{LEMS}, \sigma_{htr} = \frac{t_{night}}{n} \sum^{n} I * V * \sqrt{\left(\frac{\sigma_I}{I}\right)^2 + \left(\frac{\sigma_V}{V}\right)^2} \tag{3}$$

Table 1: Sources of Error in Power Measurements

Energy Sink	Symbol	P/N	Voltage [V]		Current [A]	
			±	%	±	%
LEMS Power Supply	E_{LEMS}	Keysight N6761A	6.00E-03	0.0160%	6.00E-03	0.0160%
Bus GSE Heater	E_{HTR}	Keithley DMM7510	7.00E-06	0.0002%	1.80E-06	0.0050%
SP RRU	ΔE_{SP}	BK Precision 9310	1.60E-02	0.05%	1.10E-02	0.30%
SP Flight		BK Precision 9310	1.60E-02	0.05%	1.10E-02	0.30%
BB RRU	ΔE_{BB}	Xantrex 60-9	0.7	-	0.2	-
BB Flight		Xantrex 60-9	0.7	-	0.2	-

The only geometric error is the 0Q heater which is a consequence of the error in the temperature measurements of the PRTs. The 0Q is intended to match the temperatures of two PRTs so that no heat will flow along the EGSE harnessing. While the sensors may read zero temperature gradient, each temperature sensor has an error of 0.71°C that can result in an unmeasured temperature gradient and heat flow. There are also errors in the expected harness conductivity, diameter, and length of the GSE harnessing as captured in Table 2. The typical formula for error propagation of multiplicative terms for a 0Q heater results in the ΔT term being a division by 0. Instead, ΔT in the error calculation is assumed to be the range covered by three standard deviations for calculating E_{0Q}. The associated systematic error, σ_{0Q}, is then just the error in the harness thermal conductance.

$$E_{0Q} = t_{night}\frac{kA}{L}(\bar{T}_1 - \bar{T}_2) \tag{4}$$

$$\sigma_{0Q} = t_{night}\frac{kA}{L}\sqrt{\left(\frac{\epsilon_k}{k}\right)^2 + \left(\frac{\epsilon_A}{A}\right)^2 + \left(\frac{\epsilon_L}{L}\right)^2} \tag{5}$$

Table 2: 0Q Harness Conductance Expected Value and Systematic Error Propagation

AWG	# Wires	Total Area (SAE AS29606B) [3] [mm2]		Material	Conductivity [W/m/K]		Length [m]		Conductance [mW/K]		% Total G
		A	±		k	±	L	±	G	±	
28	12	1.06	0.09	Copper	400	8	0.152	0.013	2.57	0.31	7.9
28	18	1.60	0.13	Copper	400	8	0.152	0.013	3.85	0.47	11.8
28	3	0.27	0.02	Copper	400	8	0.152	0.013	0.64	0.08	2.0
26	9	1.39	0.13	Copper	400	8	0.152	0.013	3.29	0.45	10.1
26	6	0.92	0.09	Copper	400	8	0.152	0.013	2.19	0.30	6.7
24	24	5.78	0.50	Copper	400	8	0.152	0.013	13.85	1.77	42.5
26	12	1.85	0.18	Copper	400	8	0.152	0.013	4.39	0.60	13.5
26	12	1.85	0.18	Constantan	20	0.2	0.152	0.013	0.22	0.03	0.7
32	16	0.51	0.05	Phosphor Bronze	40	0.4	0.152	0.013	0.12	0.02	0.4
26	4	0.62	0.06	Copper	400	8	0.152	0.013	1.46	0.20	4.5
Total Conductance									32.60	4.22	

B. Entering Cold Thermal Balance

The transition to cold balance was analyzed using the Thermal Desktop model to determine the time to reach thermal stability. Prior to cold balance, the LEMS-A3 internal components will be cooled past the cold balance set point then warmed using the Bus GSE heater. This method ensures that the bus thermal mass is absorbing heat rather than releasing it which could confound the measured bus heat loss. The analysis case begins with the bus temperatures at -33°C and the bus GSE heater setpoint ramping to -28°C. Once the avionics box temperature sensor is greater than -30°C the avionics is enabled to processor mode for 5-minutes prior to switching to the low-power hibernation mode.

The model includes a proportional-integral controller with the bus GSE heater power as the control variable and the silicon diode sensor temperature as the process variable. Integral windup was identified as an issue during early iterations of the control gains. This was addressed by implementing setpoint ramping at 5°C/h and limiting the integral error term. The heater controller gains were tuned in the thermal model and there are opportunities early in the TVAC test to test the GSE heater gains. Figure 17 shows system power while Figure 18 shows the bus temperature while entering cold balance.

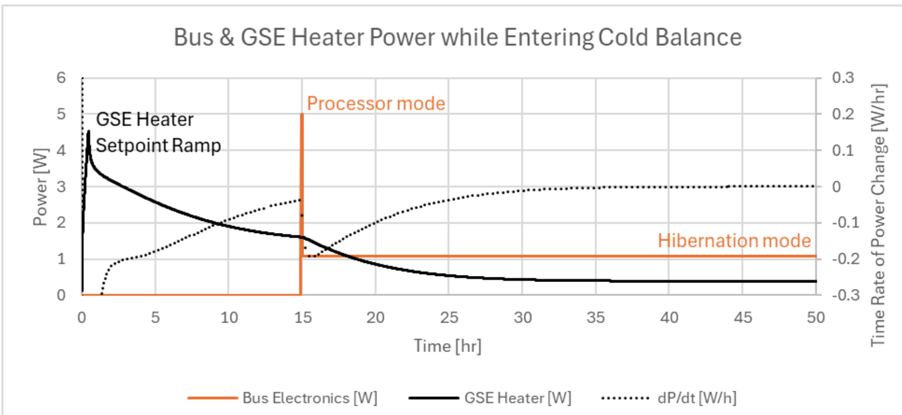


Figure 17: Transitory heater and power loads while entering cold balance

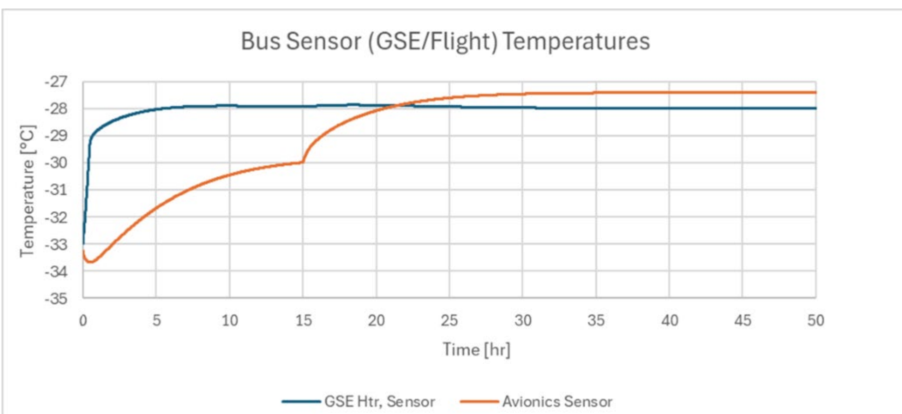


Figure 18: Key sensor temperatures while entering cold balance

C. Test Predictions and Deviations from Flight Predictions

1. Thermal Plateau Test Predictions

Figure 19 shows the expected temperatures that will be achieved during cold and hot plateaus. Where possible, components are taken to their qualification limits. In some cases like the radio, other components limit the temperatures exercised during the test. In these cases, it is acceptable that the components have achieved the predicted flight temperature ±15°C. Other external components like the solar array, coarse sun sensors, and antennae are unable to achieve their minimum predicted flight temperature because the LN2 cooled radiation sinks cannot get cold enough. A He cooled shroud was considered, but was prohibitively expensive for this test. These components were taken below flight predictions in a subsystem TVAC test with a cryocooler.

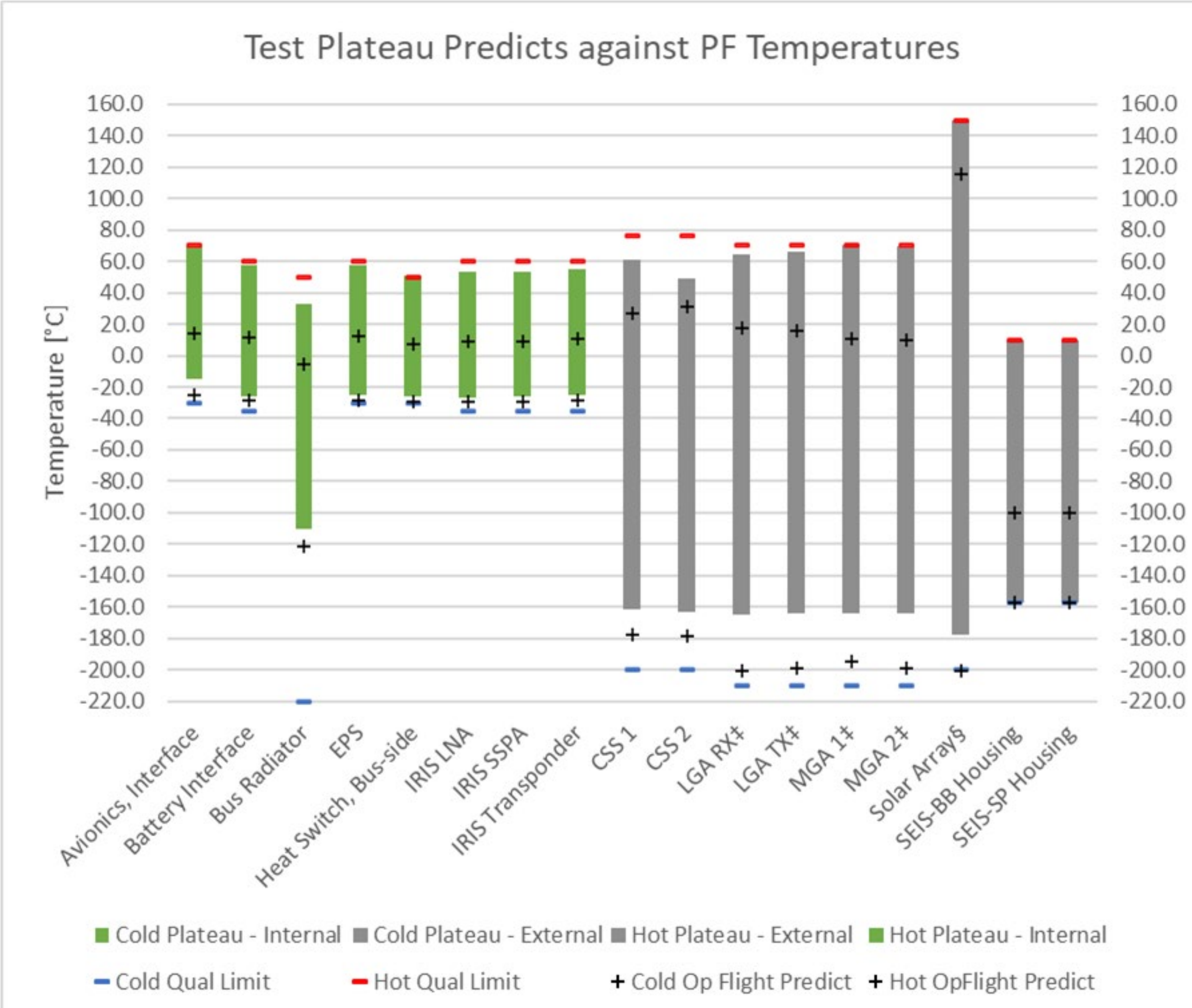


Figure 19: System TVAC Plateau Predictions Compared to Flight Predictions

2. Cold Balance Predictions and Estimated Systematic Error

Subsystem test results and model predictions were compiled to estimate the predicted nighttime energy requirement and the systematic error. Table 3 details the three standard deviation error for the 0Q heater. The differences between the flight model predictions and the TVAC model predictions are presented in Table 4 for the determination of the ΔE_{env} parameter in Eq. (1). The difference in environment between the TVAC chamber and lunar surface is predicted to result in 0.103 W less heat loss in the TVAC test compared to flight. Table 5 compiles all potential error sources for a prediction of the nighttime energy consumption.

Table 3: Expected 0Q Geometric Systematic Error

Description	Symbol	P/N	P/N	Temp. Error	Cond. Error	Total Error
Temperature Gradient [°C]	ΔT	RTX 0118MM	Modicon BMXAMO0410	1.00	-	-
Conductance [W/mmK]	$\frac{kA}{L}$	Table 2		32.60	4.22	-
0Q [W]		-		0.03	0.004	0.037
Nighttime Energy [Wh]	E_{0Q}			11.73	1.52	13.24

Table 4: Difference in Environment between System TVAC Model and Flight Model

Description	Heat Loss [W]		Delta
	Flight Model	TVAC Model	(TVAC - Flight)
Launch Lock	-0.483	-0.453	0.030
IMLI (e*=0.0028)	-0.252	-0.229	0.023
Signal and Power Passthrough (SAPP) + Coax	-0.461	-0.414	0.047
Heat Switch (JPL)	-0.458	-0.456	0.002
Bus Heat Loss	**-1.654**	**-1.551**	**0.103**
Bus Internal Electronics CBE Heat	1.082	1.082	0.000
Bus Heater (GSE Heater) Power	0.578	0.475	-0.103
Total Internal Electronics Power	1.660	1.557	-0.103
SEIS-SP As-Measured Power	0.330	0.330	0.000
SEIS-BB As-Measured Power	0.330	0.330	0.000
Total LEMS Power Consumption	**2.320**	**2.217**	**-0.103**

Table 5: Predicted LEMS-A3 System Energy Consumption during Lunar Nighttime with Systematic Error

Energy Sink	Power [W]			Predicted Energy [Wh]	
	Source	P	σ	E	σ
LEMS Power Supply	Test	1.380	2.1E-02	496.8	7.4E+00
GSE Heater	Predict	0.475	3.1E-09	171.0	1.1E-06
SP Flight - RRU	Test	0.180		64.8	
BB Flight - RRU	Test	0.180		64.8	
Change in Env.	Predict	0.103	0.0E+00	37.1	0.0E+00
0Q Heater	Predict	0.000	3.7E-02	0.0	1.3E+01
Totals		2.318	4.2E-02	834.5	1.5E+01

The flight battery has a measured energy capacity at -30°C of 940.8 Wh. The maximum predicted energy consumption for a nominal lunar night, including systematic errors set at three standard deviations, is 849.5 Wh. This leaves 121.3 Wh to account for random errors from sensor noise. The level of random error from sensor noise will not be known until the test is conducted but this margin is expected to be sufficient. When the extrapolated energy consumption including systematic and random errors is less than the battery capacity, LEMS-A3 will have demonstrated ability to survive and operate the lunar night.

VI. Conclusion

The TVAC test profile to qualify LEMS for spaceflight was discussed. The TVAC test setup is designed to simulate environments representative of a hot solar noon case and a cold lunar night case. A technique was demonstrated to perform a partial cold GN2 backfill to 67 pa (0.5 torr) in order to accelerate hot to cold transitions and facilitate achievement of cold balance. This technique is expected to reduce cooldown transition from about one week to about one day. The cold lunar night case is critical for verifying that LEMS is able to survive the lunar night for at least 15 Earth days. The methodology to achieve and measure adequate stability criteria was developed and is expected to have adequate margin to account for random error in the signal noise.

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