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SURVIVE THE NIGHT
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Lunar Environment Monitoring Station (LEMS)

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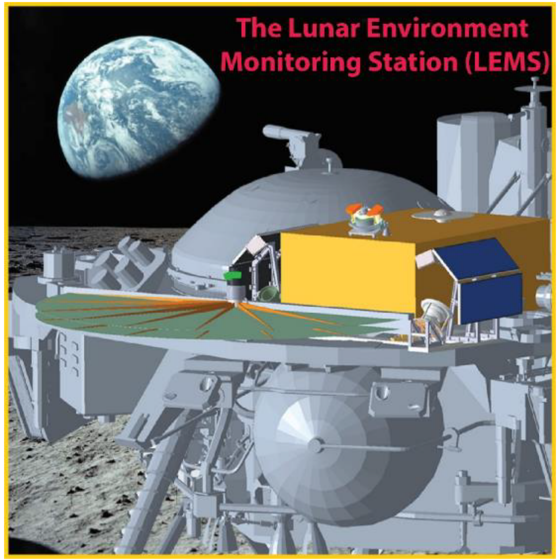
What is LEMS ?

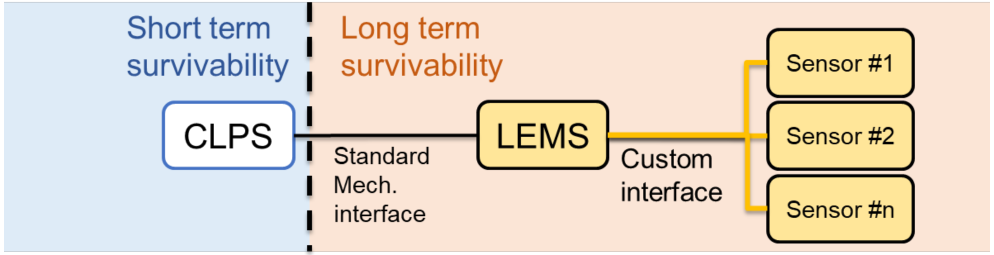
LEMS is a **compact**, **autonomous**, and **self-sustaining** instrument package that enables **multi-year, in-situ,** monitoring of the lunar geophysical environment.

- It is a self-powered, self-managed, and self-communicating flight system that provides all attributes of a science mission.
- It conducts science observations on the lunar surface continuously (day and night).
- It is fully autonomous, requires no assistance, and is agnostic to the method of delivery (CLPS or Artemis).
- It is designed to be easily deployable and to accommodate various science goals, instrumentation, and mission scenarios.



Why LEMS? (1)

- Augmentation to the current capabilities of CLPS:
  - ✓ Many key geophysical measurements require sensors to operate for long durations (several years), beyond the current technical and operational capabilities of the CLPS vehicles.
  - ✓ The self-sustaining architecture of LEMS:
    - guards the CLPS from having to survive beyond a few days on the surface of the Moon.
    - provides the thermal/power/comm. resources for sensors requiring long-term operations.
    - provides a simple and standard mechanical interface to CLPS.



Why LEMS? (2)

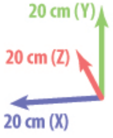
- Ideal package for delivery by crewed missions:
  - ✓ LEMS provides a standalone, all-in-one science package that minimizes crew workload during deployment.
  - ✓ Unlike the Apollo ALSEP:
    - ✓ LEMS is a single easy to handle package
    - ✓ doesn't require fine positioning or pointing
    - ✓ doesn't require electrical setting up

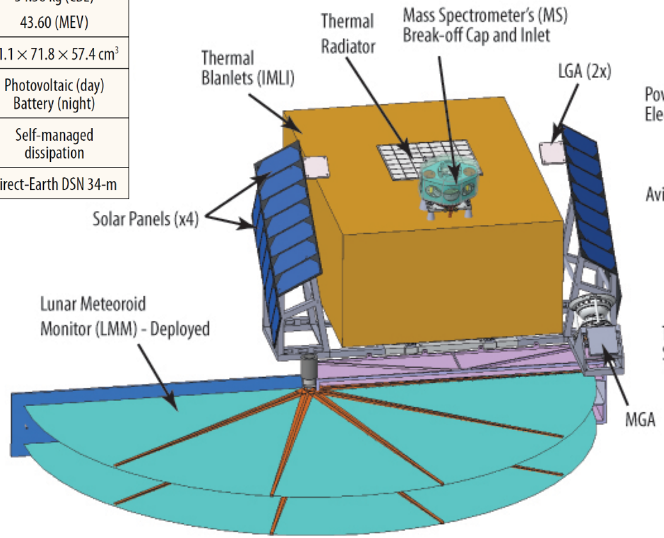
LEMS all-in-one package

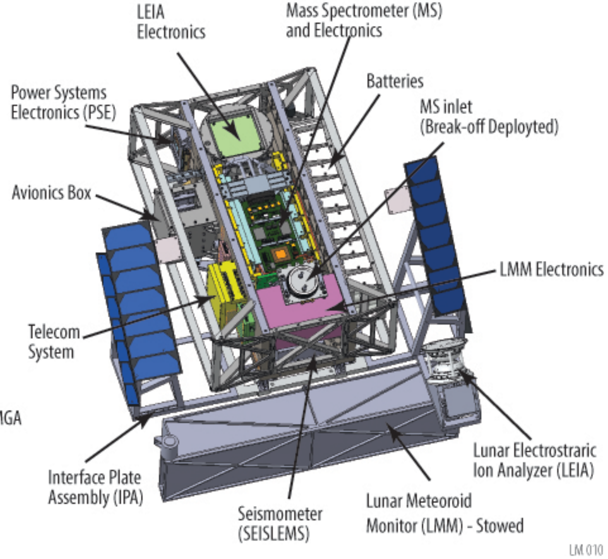
LEMS Architecture

- In its flight version, LEMS is designed to carry a **lunar interior and exosphere science package** composed of a Mass Spectrometer (MS), a Lunar Micrometeoroid Monitor (LMM), a Lunar Energetic Ion Analyzer (LEIA), and a 3-axis Seismometer (SEISLEMS).

LEMS Summary Specifications	
Mass	34.36 kg (CBE) 43.60 (MEV)
Volume (stowed)	81.1 × 71.8 × 57.4 cm^3
Power	Photovoltaic (day) Battery (night)
Thermal	Self-managed dissipation
Telecom	Direct-Earth DSN 34-m



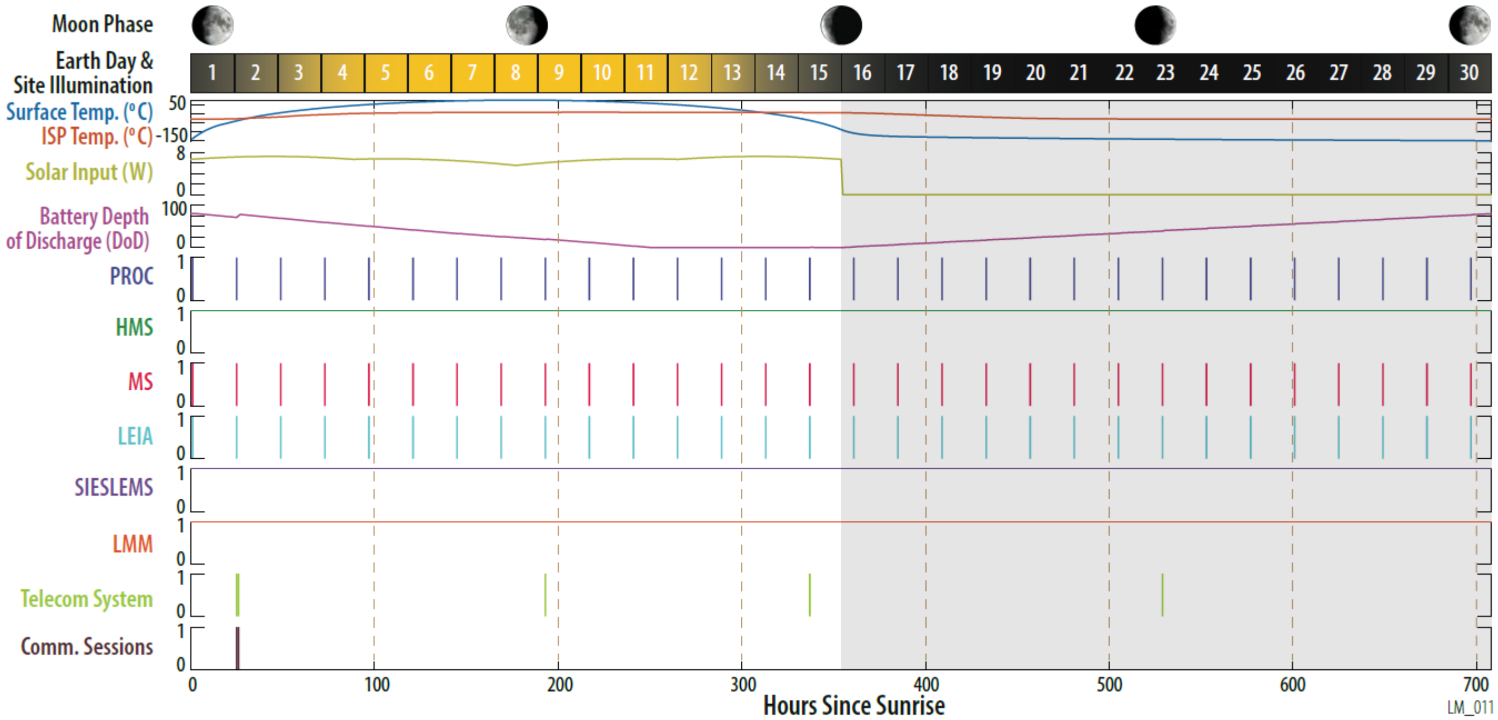




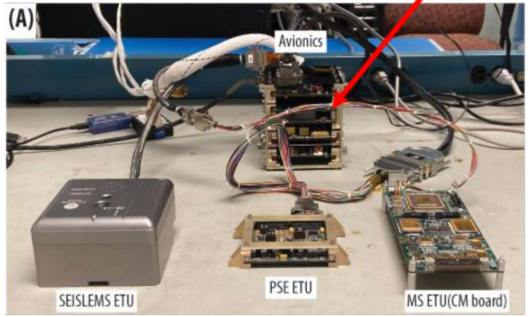
Concept of Operations (1)

- LEMS manages its thermal and power states by alternating periods of low-power operations, during which the station is in partial "hibernation," with periods of high-power operations:
  - During "**awake**" periods, all science sensors are active and collecting data.
  - During "**hibernation**," only the Seismometer and Micrometeoroid Monitor collect data.
- Operations start after station is on the surface and continue for the lifetime of the mission:
  - LEMS is designed to initiate autonomous operation on the surface after activation by the CLPS lander or Artemis crew.
  - The Seismometer and the Lunar Micrometeoroid Monitor collect data continuously day and night, while the Mass Spectrometer and the Energetic Ion Analyzer conduct measurements every 24 hr.
  - Collected data are downlinked monthly via DSN link.

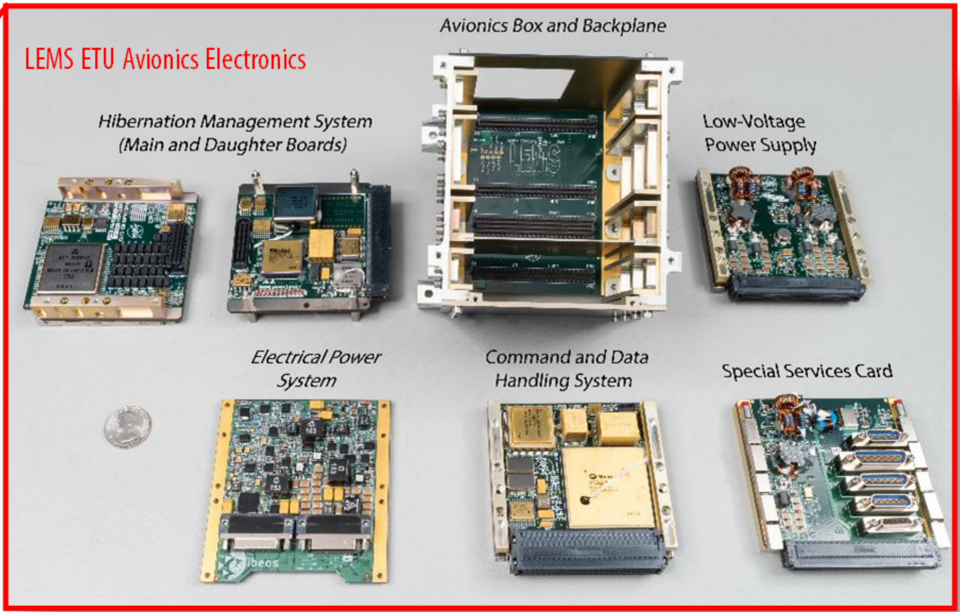
Concept of Operations (2)



Electrical Development

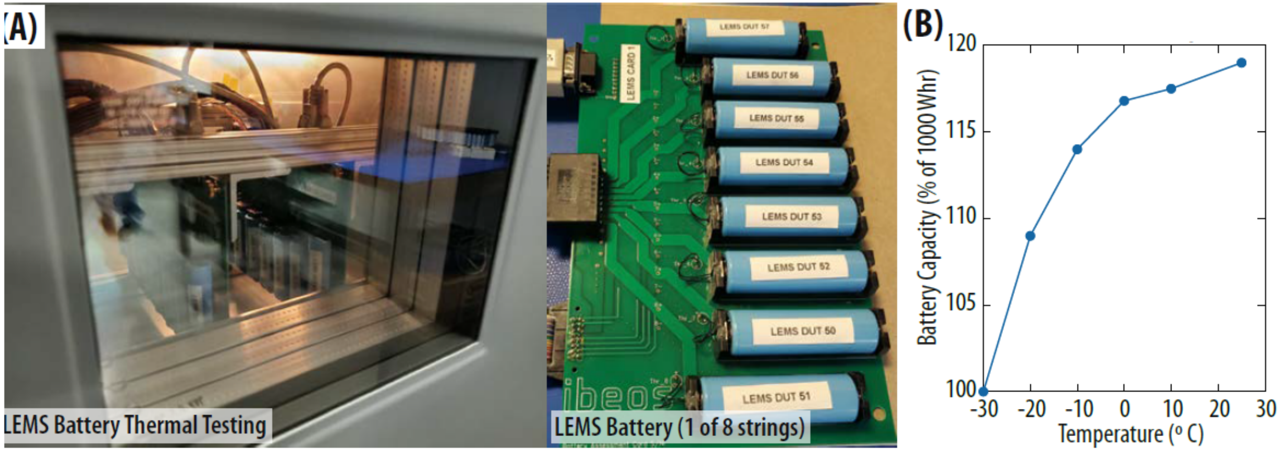


Flat-sat testing of Avionics with seismometer and mass spectrometer, demonstrated end-to-end functionalities.



- The LEMS team developed an integrated and power efficient Avionics electronics that enables autonomous and continuous operation on the surface of the Moon.
- An ETU-quality Avionics and Power Electronics were manufactured and tested to validate system capabilities.

Power Source Development

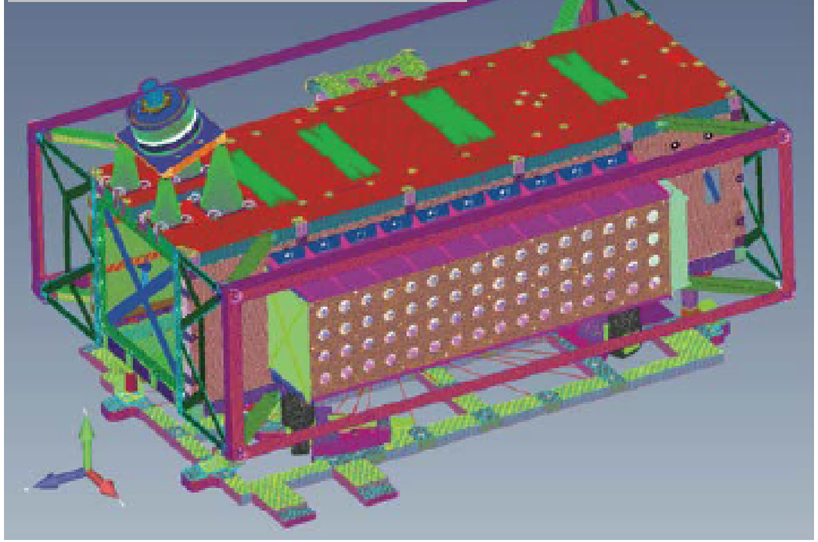


- LEMS sustains operations during lunar night using 1200 Whr Li-ion battery:
  - Cell performance was characterized and qualified over LEMS internal temp range (-30°C/+50°C).
  - The cells functional performance was also demonstrated for the cyclical operation power load expected over a lunation.

Mechanical Development

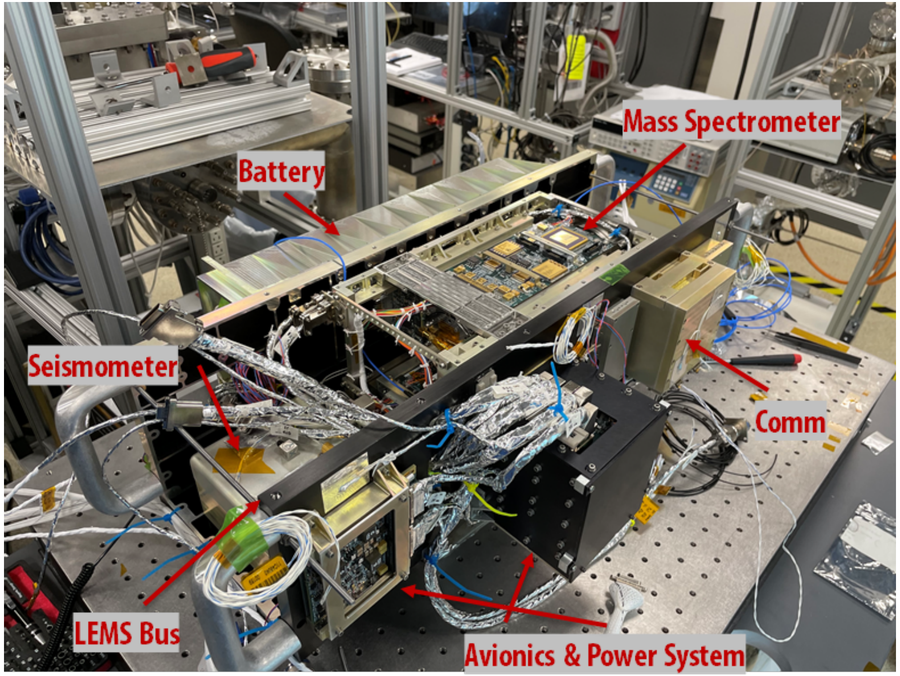
- High fidelity finite-element model (with NASTRAN) was used to demonstrate system compatibility and positive margins to GSFC's General Environmental Verification Standard (GEVS).

LEMS High Fidelity Structural Model



Integration and Testing

- All elements of the LEMS system (including mass spectrometer and seismometer) were integrated into a high-fidelity Engineering Unit.
- The team used flight-like processes and workmanship to validate integration procedures and resulting schedule.



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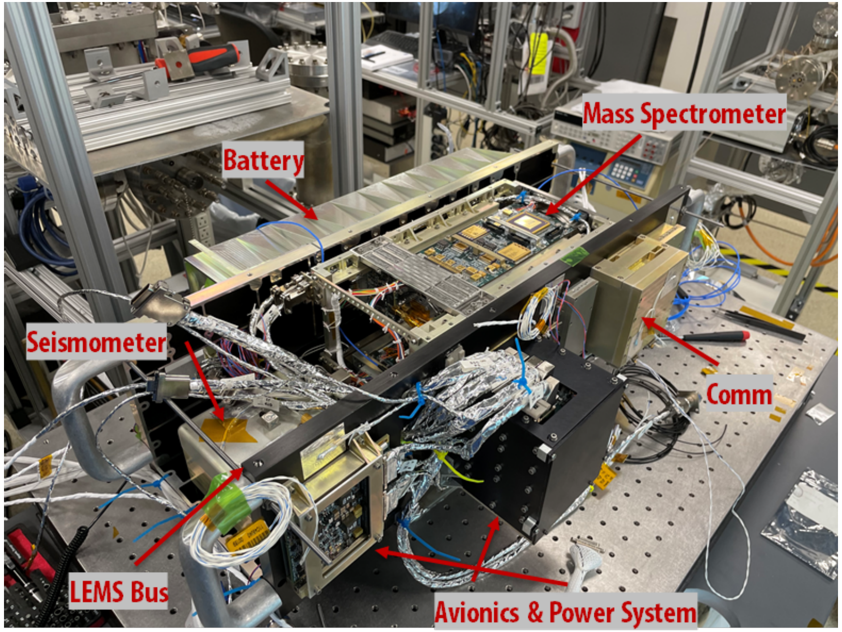
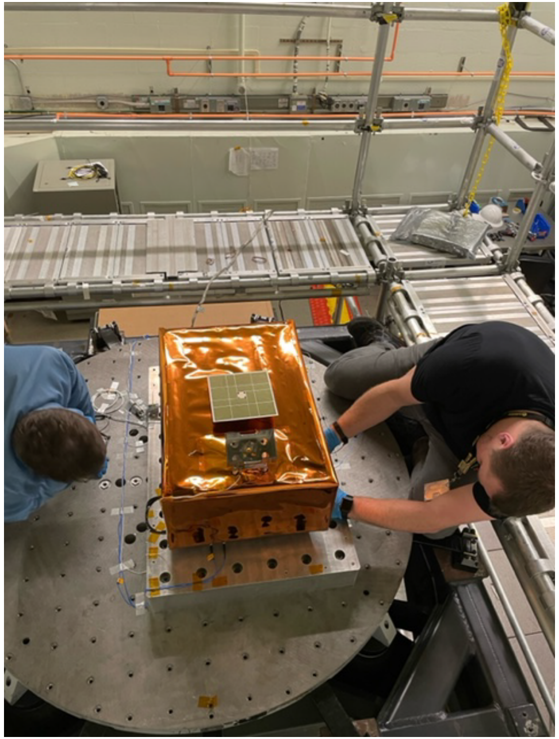


LEMS ETU prior to closeout and installation of thermal IMLI and launch lock mechanism.

Vibration Testing

- LEMS was successfully tested along 3-axes for vibration at GEVS Qualification Level:
  - Mass adjusted GEVS Qualification Level = 12.3 Grms for 34 kg.
  - Reponses measured by accelerometer sensors placed at critical location inside LEMS.
  - Signature sine sweep tests were performed before and after each axis of random vibration testing.
  - Measured system responses are within predicted levels at all frequencies.



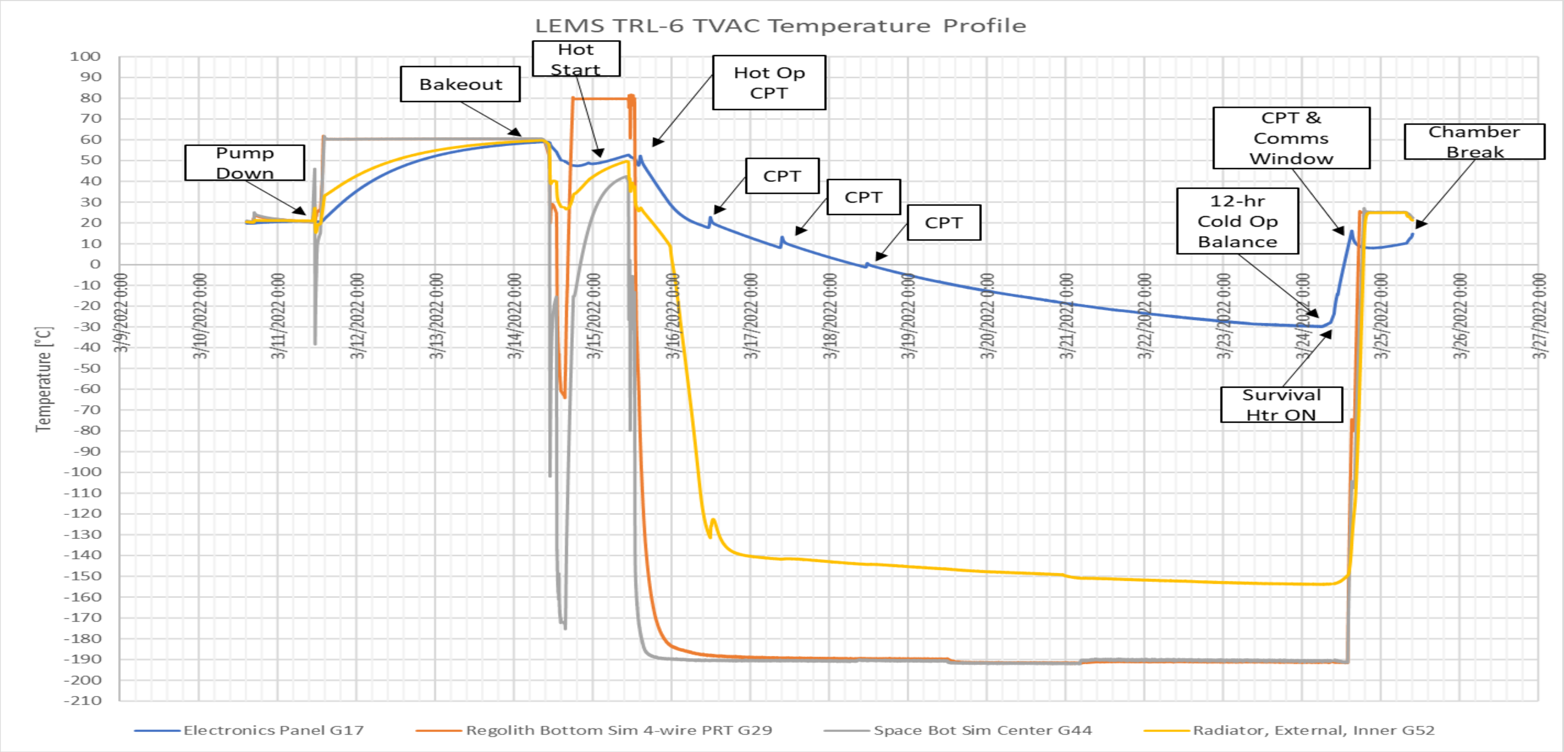
Preparation for Vibration Testing 02/28/2022

Thermal-Vacuum Testing

- LEMS was successfully tested for operation at stacked worst case hot and cold environmental conditions seen on the lunar surface. This test aimed to:
  - Verify steady state operation at worst case hot and cold environmental conditions.
  - Verify nominal daily concept of operation “day-in-the-life” (both science and weekly communication) at worst case hot and cold environmental conditions.
  - Take thermal balance measurements at worst case hot and cold environmental conditions.
  - Validate that LEMS power and thermal systems are compatible with continuous self-sufficient operations day and night.

Preparation for Thermal-Vacuum Testing 03/08/2022

Thermal-Vacuum Testing



Summary of Environmental Testing Results

- Demonstrated compatibility with launch environment with a dedicated launch lock system.
- Demonstrated mechanical deployment post landing.
- Comprehensive Performance Tests (CPTs) demonstrated operability of all LEMS subsystems in flight-like conditions (external temperatures from 60°C to -190°C).
- Temperatures inside the bus remained within operations levels (-30°C to 45°C).
- The total heat leak during lunar night (15 days) was measured to 1200 Whr, within the LEMS battery energy capacity.
- LEMS electronics accumulated more than 300 hours of uninterrupted and fault-free operations.

Take away message

LEMS provides

a compelling solution to start conducting needed long-term science observations at the Moon

and

a path to rapidly mature a unique longevity capability that expands the capacity of the CLPS program without levying additional requirements on the CLPS landers.