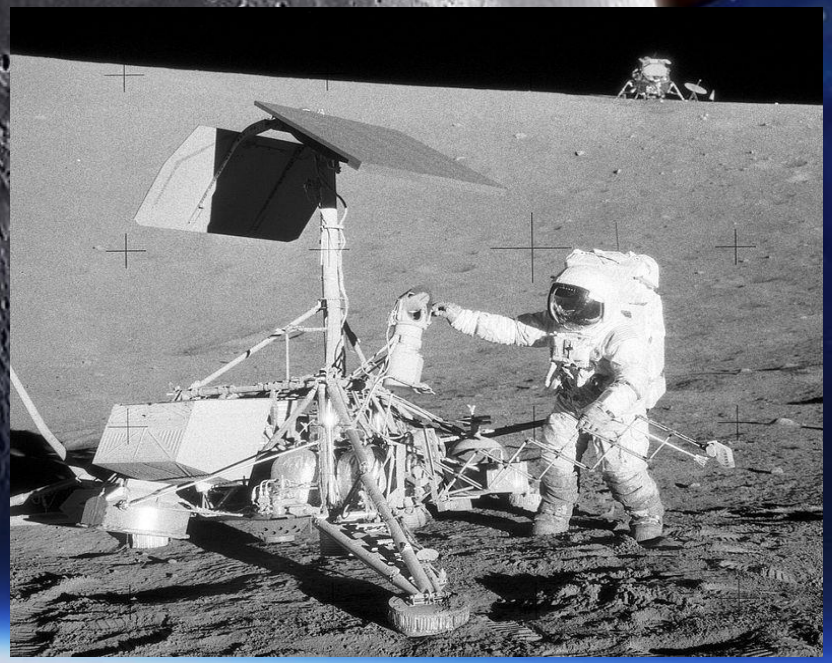
National Aeronautics and Space Administration

# Battery and Electronics Technologies for Lunar Power Hibernation

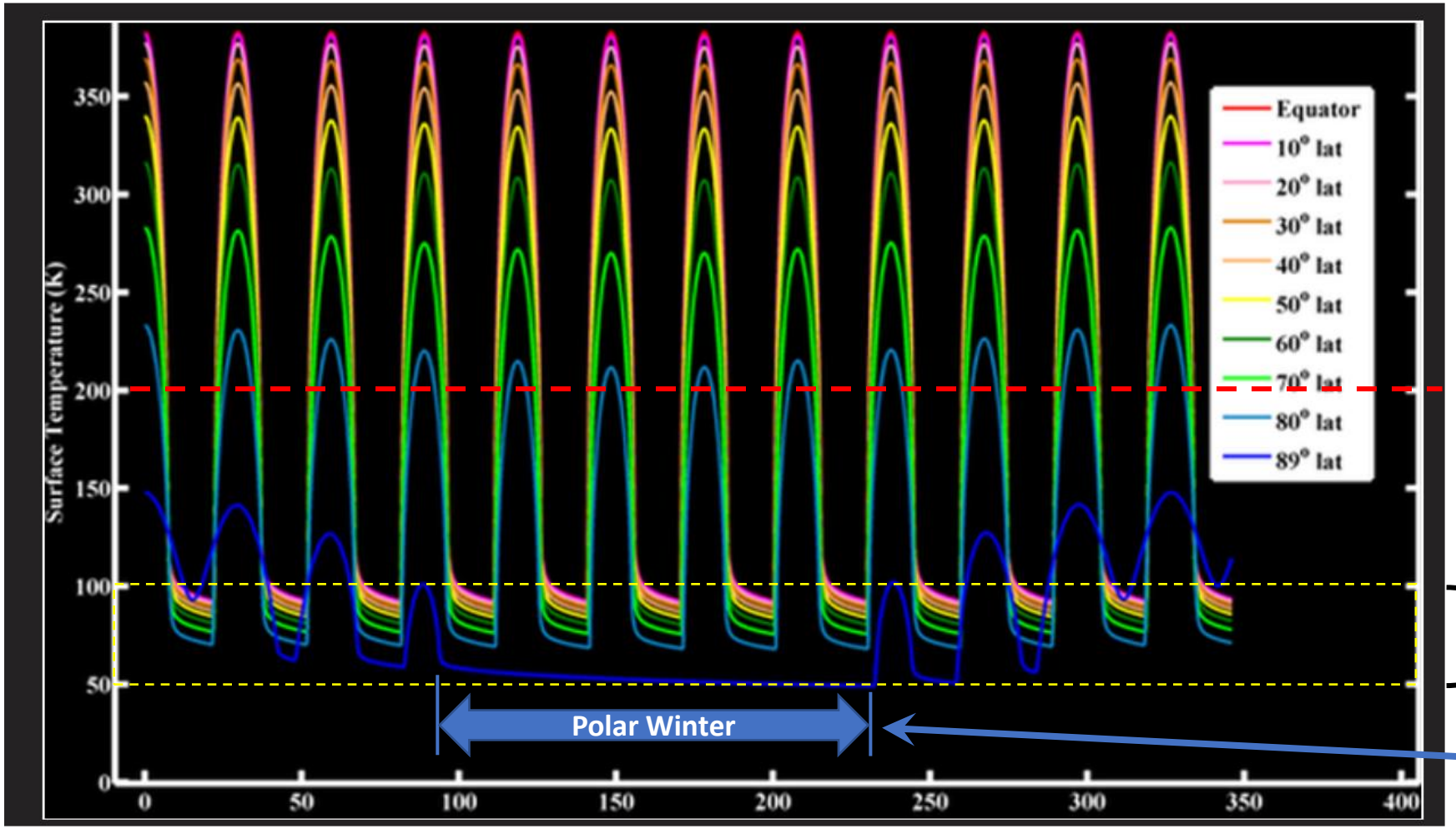
***LSIC: Low Temperature Sub-kW Power and Energy Storage for the Lunar Surface Workshop***
***July 28, 2022***


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NASA Photo: Apollo 12 visits Surveyor 3

# Lunar Reconnaissance Orbiter Data:
# Lunar Day/Night Temperatures by Latitude




**Lunar Night Temperatures are extremely cold *Everywhere.***

**Lunar Night is 354 hours.**

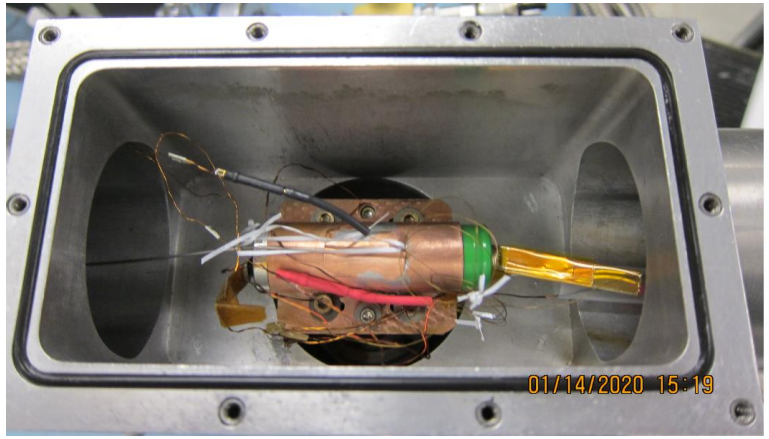
**<-- Li-Ion Battery Approx. Freeze Temperature**

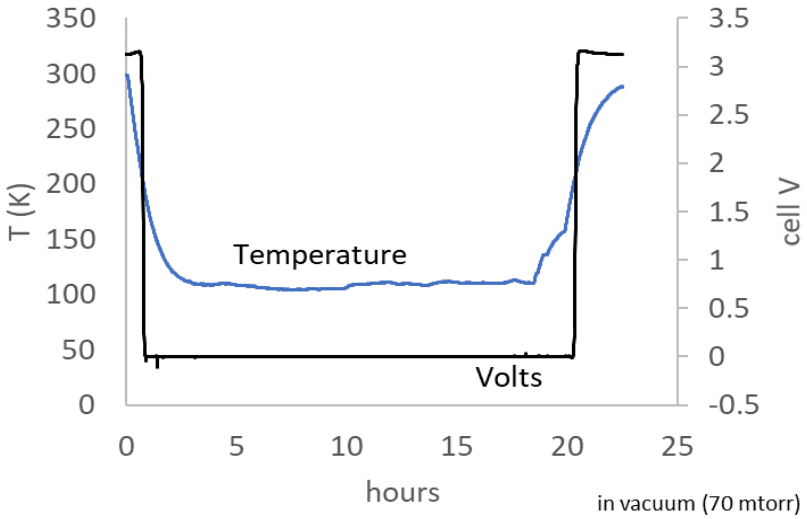
**Lunar Night Temperatures**

**Polar Winter (4 ½ Months) Temps down to 50K**

Permissions per Dr. N Petro/NASA GSFC and Dr. D Paige/UCLA

# Li-Ion Tolerance Low Temperatures




Photos courtesy of W. Bennett NASA Glenn

**Tests Demonstrate Li-Ion 18650 cells can actually survive the freeze/thaw cycle.**

- Cells recover SOC when returned to normal temperatures.
- Implies that a spacecraft could "**Hibernate**" through the night.

**Lunar Dawn Recovery**

- Depends on "Cryo-Operable" electronic controls capable of a cold-start and operating at cryogenic temperatures.
- For Safety, the Battery is isolated until returned or normal temperatures.
  - Power electronics must start on solar array output alone.
  - The system will need to tolerate initial low power quality

**Hibernation Technology Research described in a STMD solicitation**

- **Described in Topic 2**: STMD Space Technology Research Grants Program, Early Career Faculty (ECF22) solicitation: (released Feb 22)

# Battery & Electronics Technology for Hibernation

## Research areas described in Topic 2 of ECF22 solicitation include:

- **Characterization of Lithium-Ion cells cycling through the freeze-thaw process down to 50K**
  - Little is known about transition between normal and frozen states within Lithium-Ion cells
    - Electro-Chemistry Effects
    - Thermal-Mechanical Effects (cell structure, seals, built-in safety devices).
- **Cold-cell diagnostics and safing controls.**
  - Diagnostics to detect faults while the cells are still in a low energy state.
  - Safing controls may exploit cold environment to slowly dissipate energy and prevent thermal runaway.
- **Power Electronic Circuits that operate over a 50K to 400K**.
  - **Ideally**, circuits are composed of devices that are insensitive to temperature.
  - Use devices with flat response to temperature. (Gallium-Nitride)
  - Develop temperature compensation techniques to cover the 50K to 400K range.
- **Characterization and modeling of power electronics for 50K to 400K (Typically 125C to -55C)**
  - Requires thorough characterization of electronic devices over the temperature range.
  - Develop a physics-based model to simulate cryogenic effects like “carrier freezeout”.
  - Accurate models are needed support future cryo-electronics circuit design.

# Battery & Electronics Technology for Hibernation

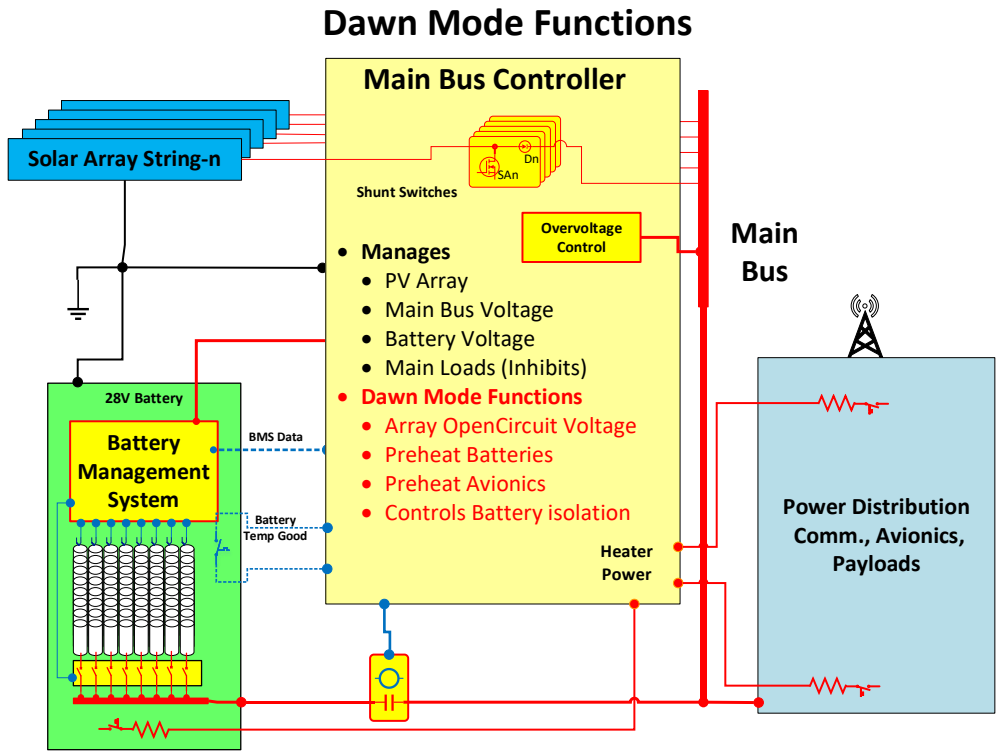
**NASA Glenn progressing toward a Hibernation Technology Demonstrator.**

- Employ the developments of the ECF Researchers and other STMD developments
- Demonstrate a Hibernation Battery and Battery Management System
- Demonstrate Cryo-Electronic "Main Bus Controller" with "Dawn Mode" recovery functions.

**In Summary**

**"Lunar Power Hibernation" improves Science ROI.**

- Aimed at low-cost lunar landers, rovers and payloads relying on Solar Power and Batteries.
  - Minimizes mass changes to existing hardware
  - Extends mission life beyond the single cycle
- Applicable to future lunar robotic systems
- Improves compatibility with lunar environment and overall robustness and survivability





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