NASA'S WATTS ON THE MOON CHALLENGE

UC SANTA BARBARA

NASA CENTENNIAL CHALLENGES

HELPS System & GRC Test Overview

UCSB Experimental Cosmology Group

09/20/24

H.E.L.P.S.

H - High

E - Efficiency

L - Long-range

P - Power

S - Solution

Objective:
Provide ~ kW power over 3 km distance
High efficiency, low mass power delivery
Fully autonomous, auto fault tolerant
Operate at cryogenic temperature (lunar night)
Ideally extendable to higher power/ distance
Ideally extendable to lunar day capability
Ideally capable of solar, nuclear… power input
All objectives were met

Team Members

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Marlon Munoz
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Jon Suen
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Bryan Phillips
Engineer

System Hierarchy (800 V DC transmission line)

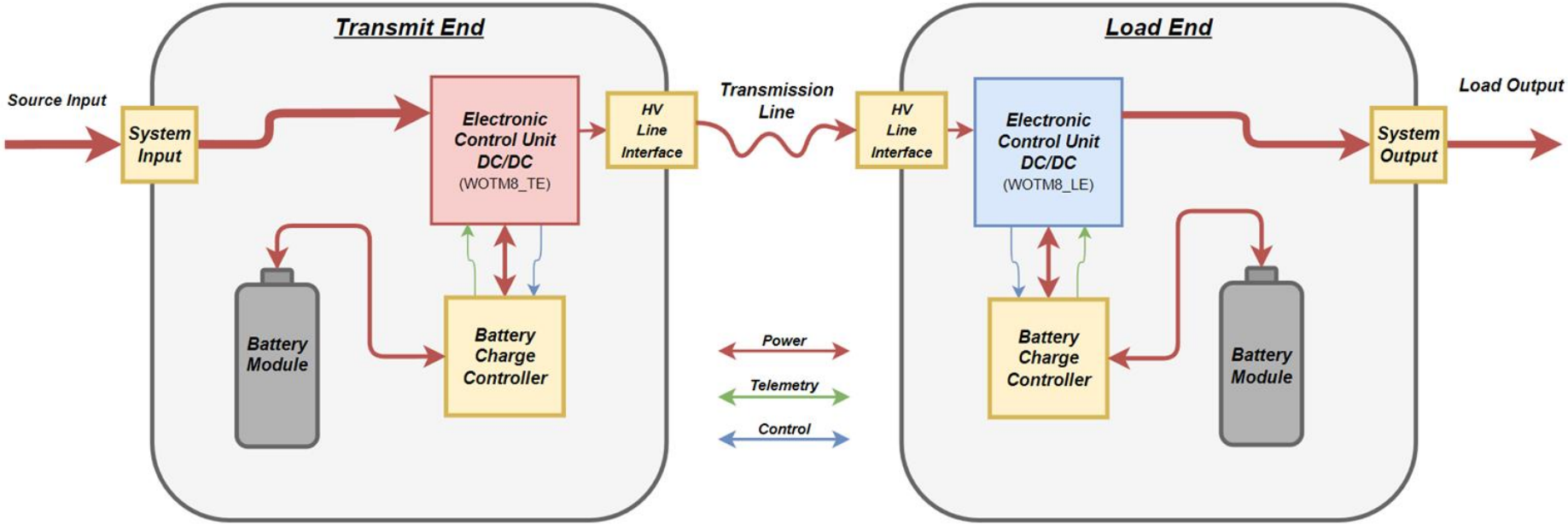
As built our system can also use solar input (MPPT included)

Wide Source input range 60-150 VDC – RF telemetry developed

As built system can provide 1.75 kW continuously if needed (not needed for WOTM)

→Note our system topology uses storage at both source and load←

This minimizes power on transmission line – 250w average – lower mass higher efficiency

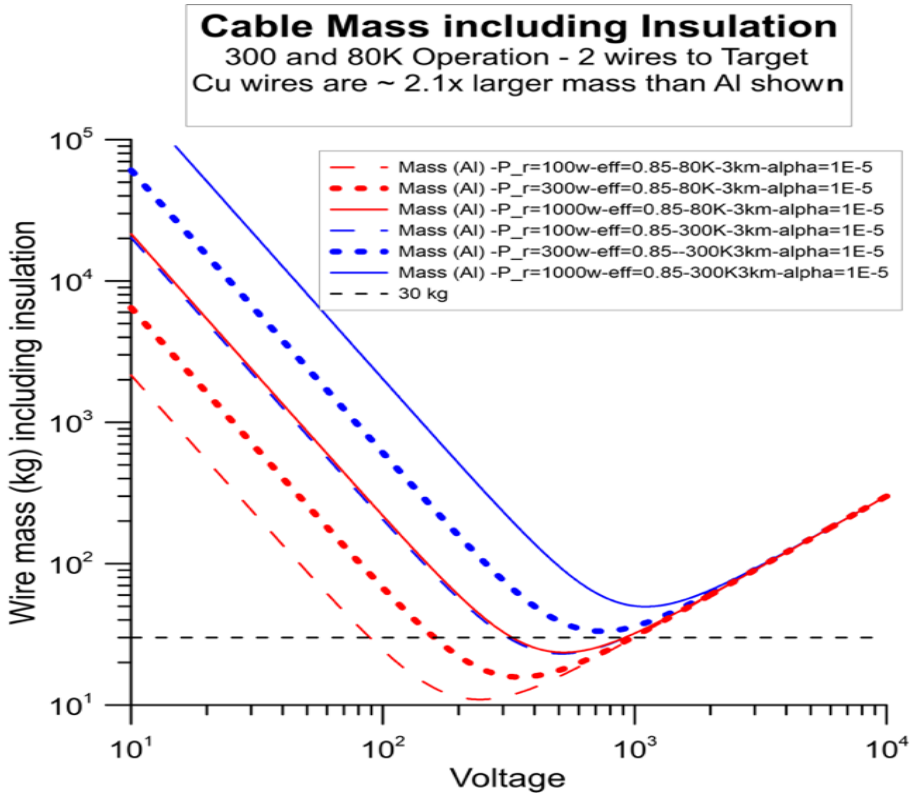


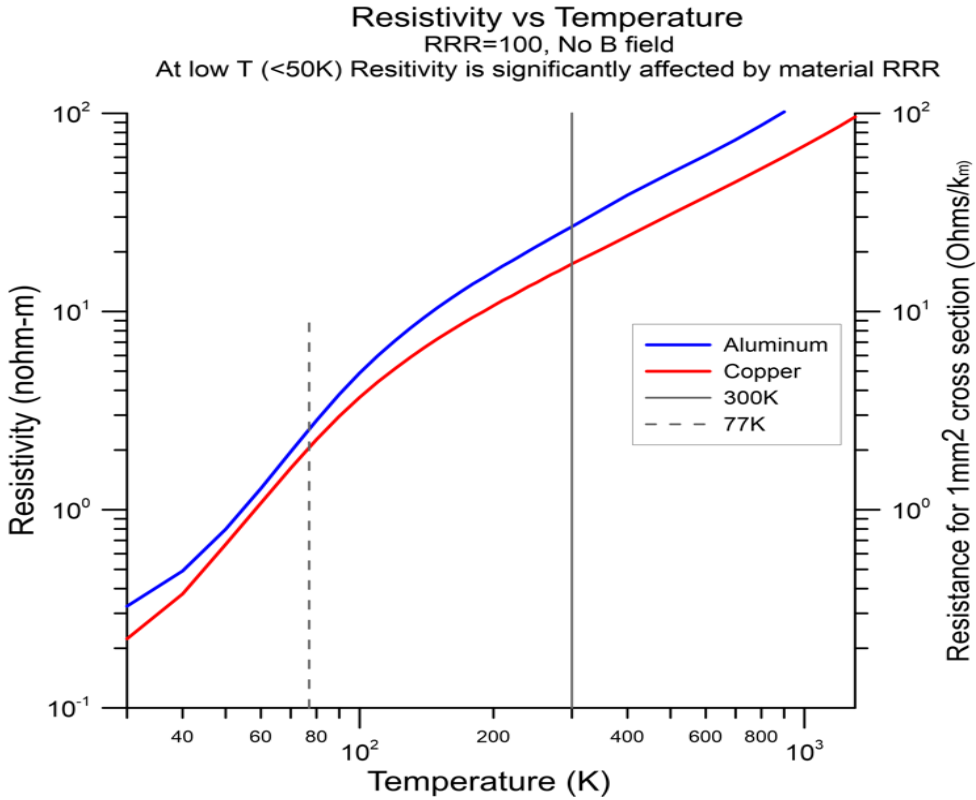
Transmission Line Operational Trade Space

3 km Transmission Cable Mass Minimization vs Transmission Line Voltage

Low voltage = Conductor mass dominated – High Voltage = Insulator mass dominated

→Our custom thin film 3 km transmission line mass is 16kg (5.3 kg/km)←





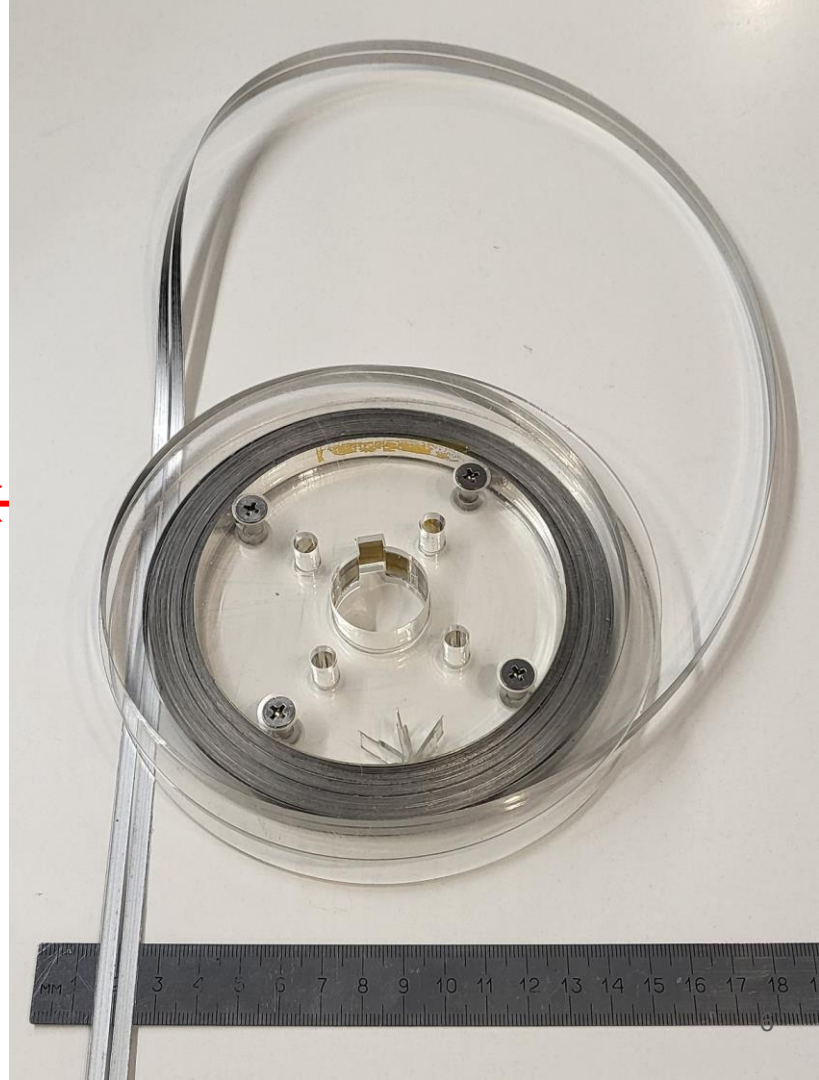
Thin Film Hybrid Normal + HTS Cable

Warm (normal metal) + Cold (SC)
Allows 0-400K operation
Cu+HTS (Cu + YBCO) 12.5 kg/km

→Al only (Used for WOTM test) cable 5 kg/km←

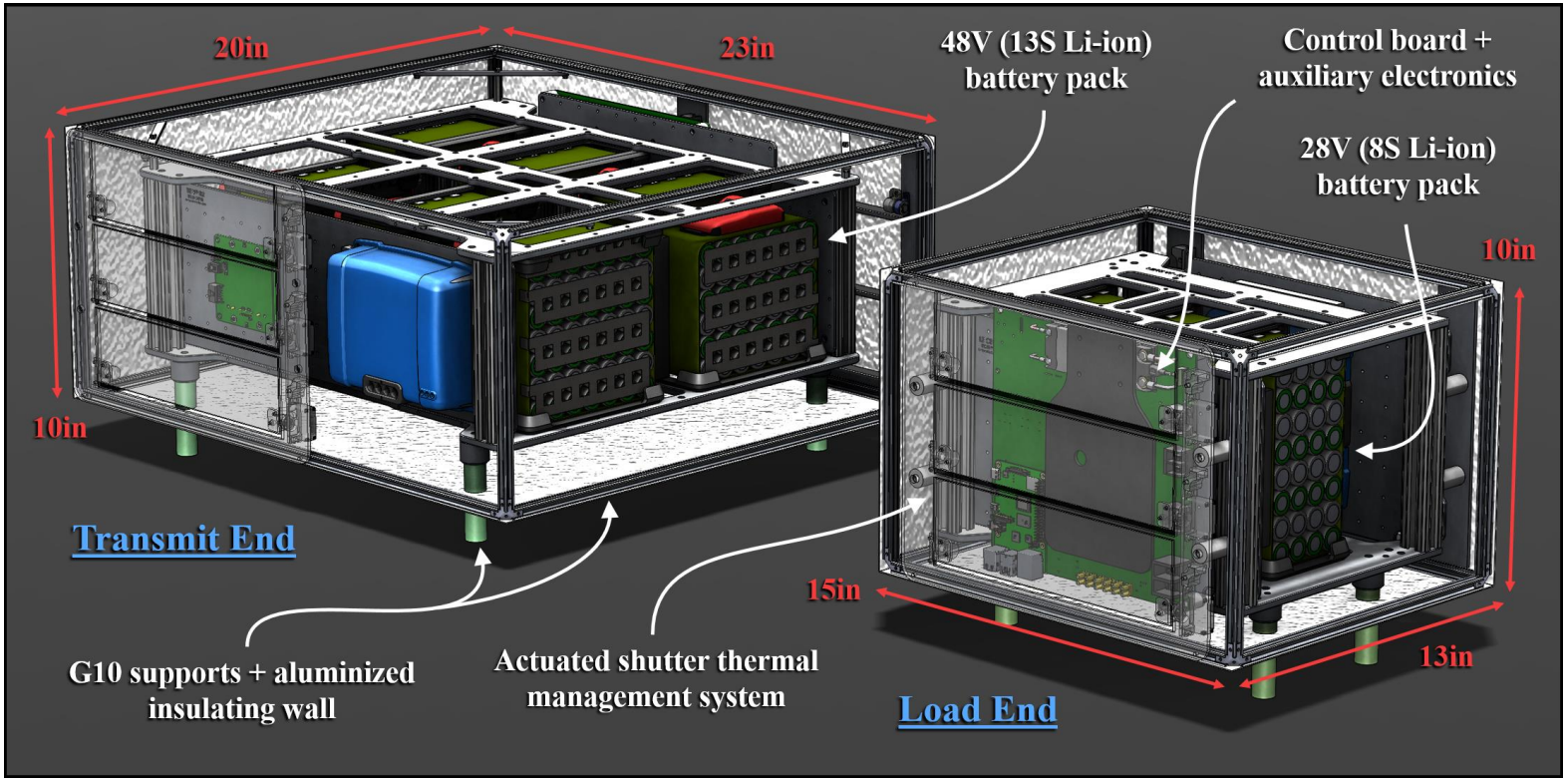
HTS cable portion capability
>200A @ 77K
→200kW @ 1 kV (77K) ←

WOTM program was 0.8kV
(Works at >2kV IF needed)
→Scalable to >1 MW (77K)←



Thermal Management & Mechanical Design

Actuator Radiator Thermal Control – Source and Load Side Same
Actuated Shutters for Radiative Cooling – Daylight Adaptable

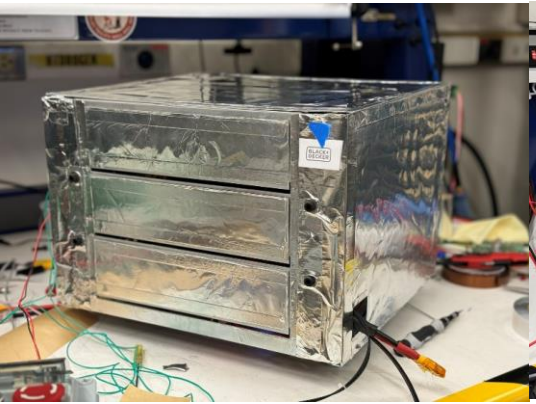


Watts on The Moon – Glenn Research Center Test 8-5-24

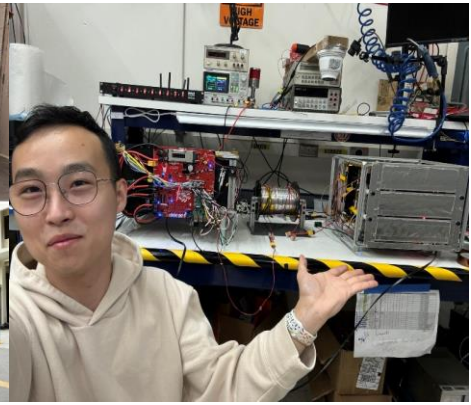
Full scale for kilowatt class system over 3km – cable shown is 30 m for test chamber – cable 5 kg/km

Primary Power Conversion density 14 kW/kg (You see mostly batteries in this system) – This Unit Scalable to 14 kW

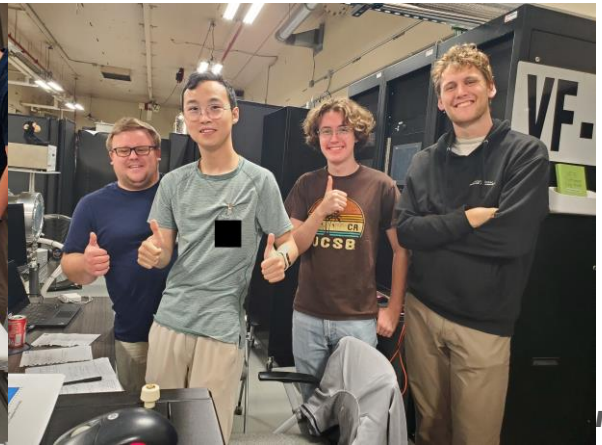
Related system scalable to >100 kW





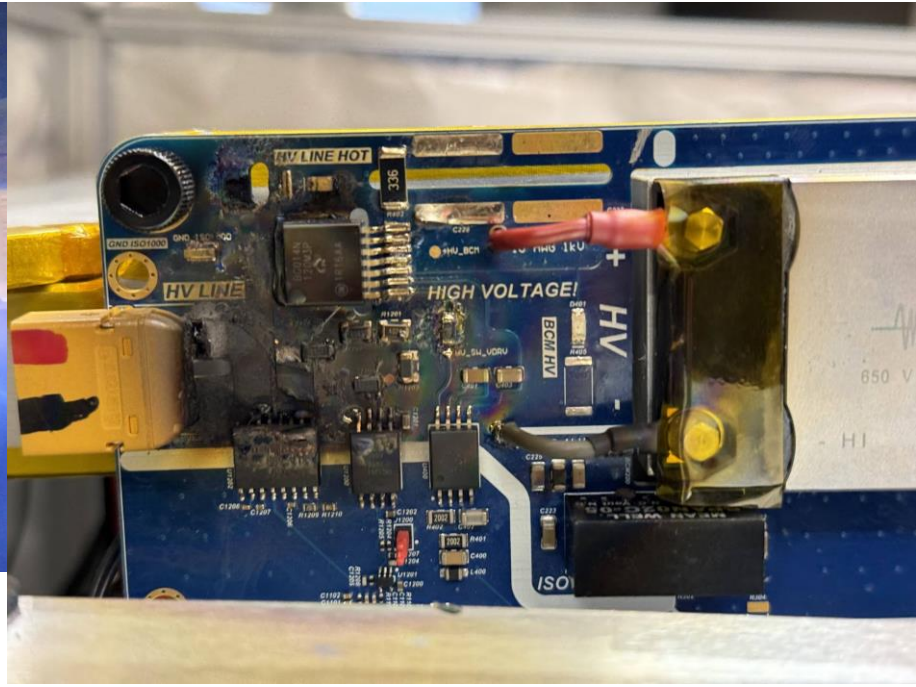




roup

We blew up a few parts along the way!

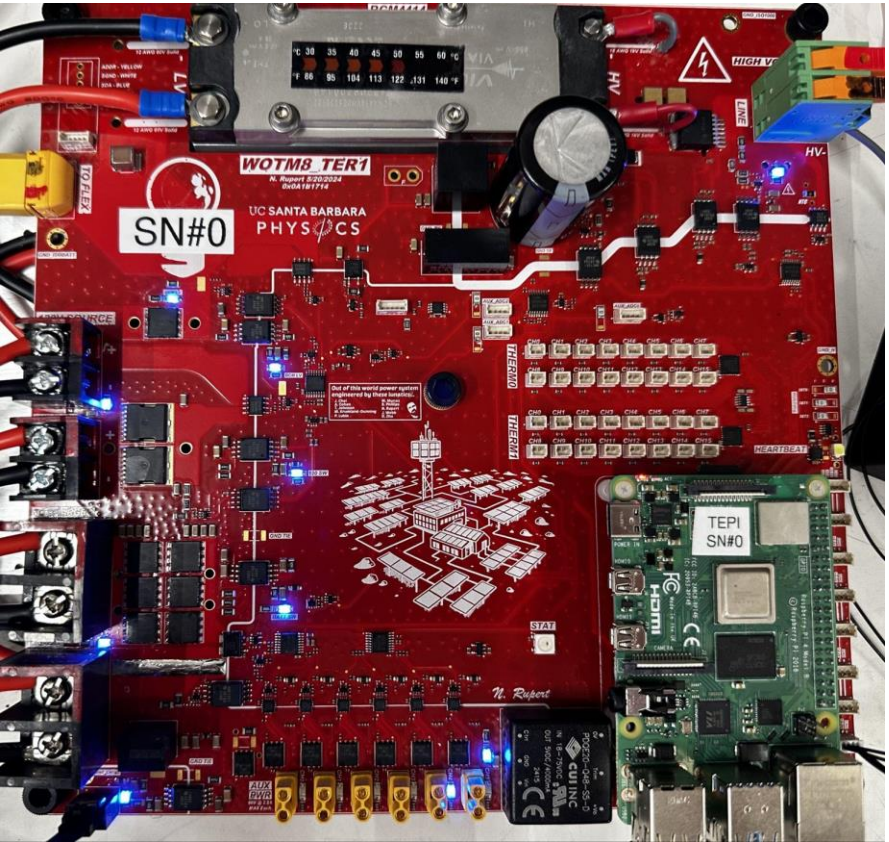
No pain no gain!

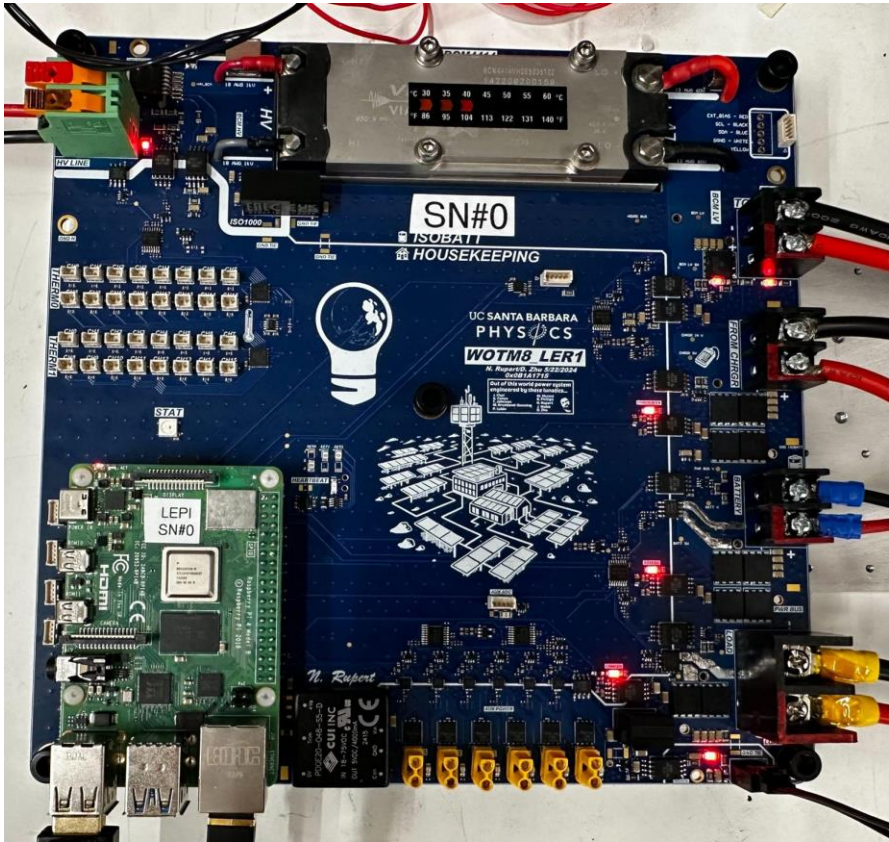


Phase 3 Final Prototype Version 1 - Mid 2024

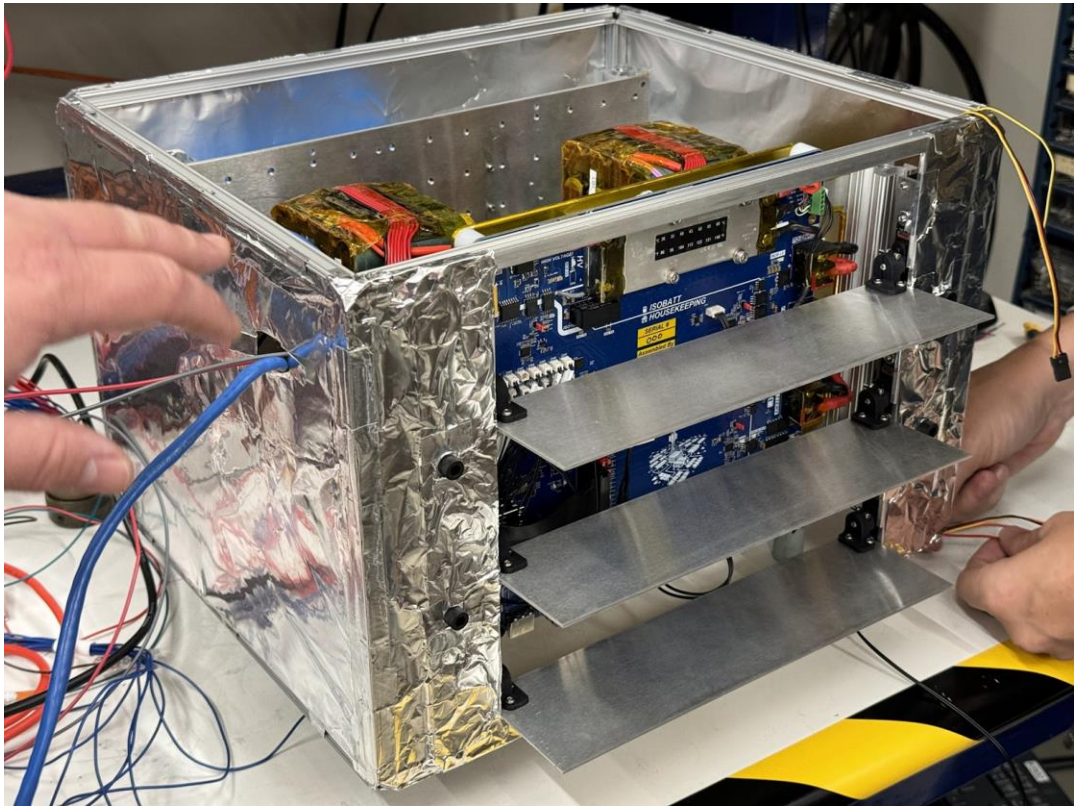
Total Board Mass 450g including 140g 1.75 kW 800VDC Converter (12.5 kW/kg)

→System mass completely energy storage requirement dominated←



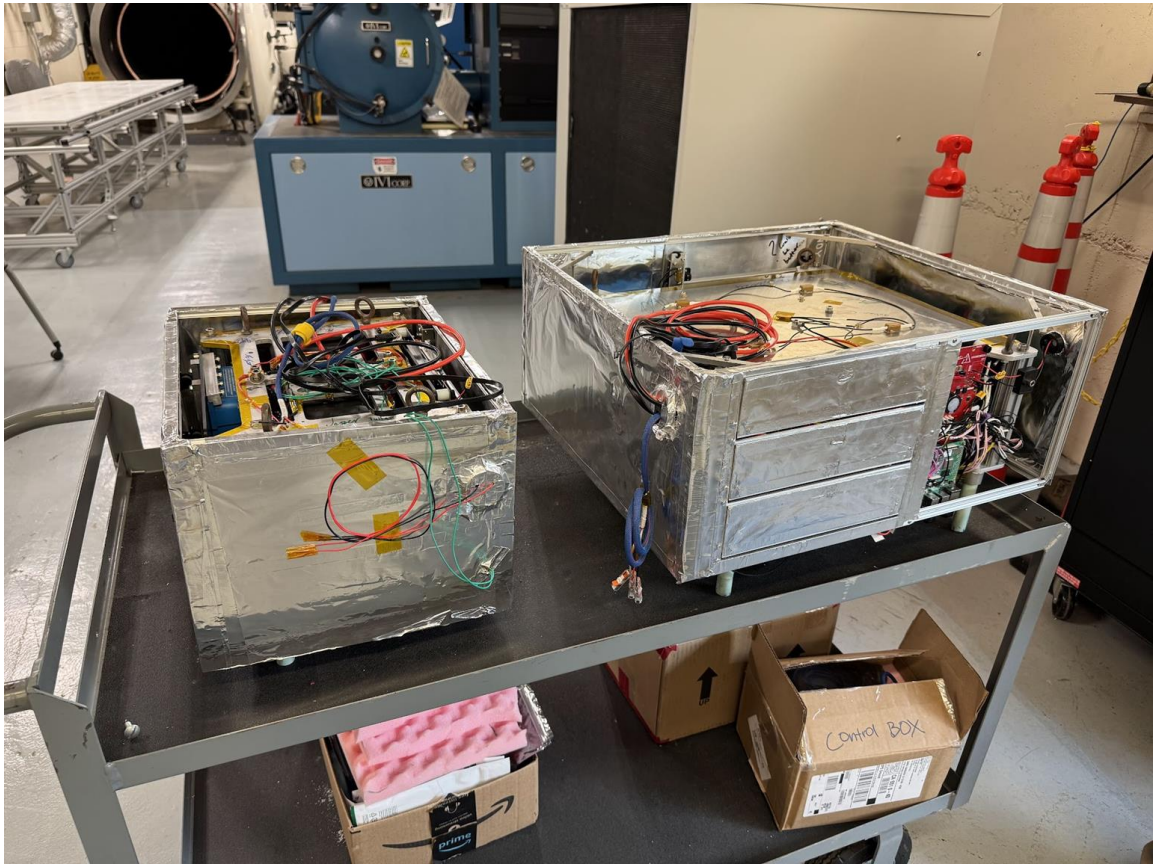


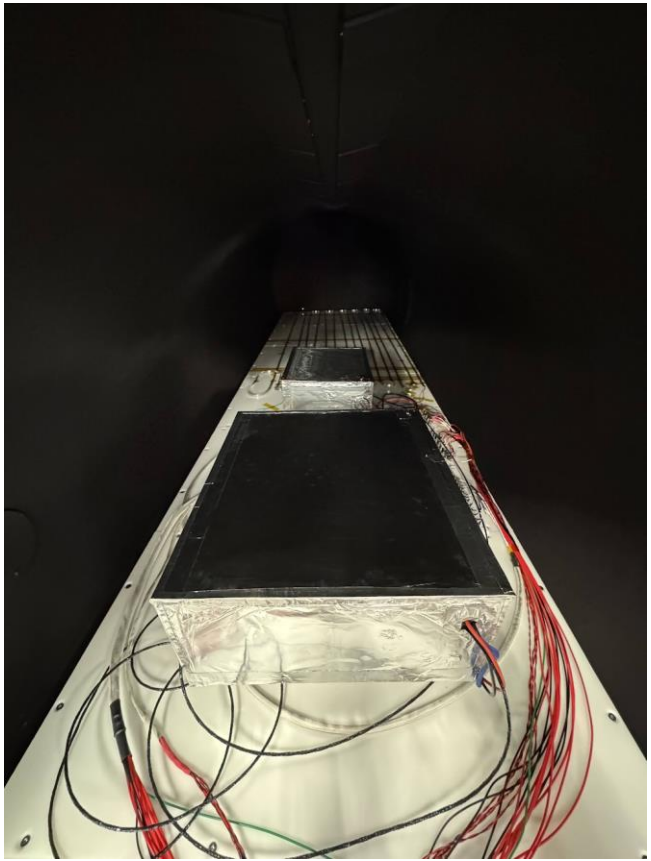
Final Revision with Thermal Solution - Early 2024



- Aluminum and foil exterior
- Shutters exposes radiative cooling plates or electronics to VF-3 cold wall for cooling
- 32 temperature sensors monitors temperature and controls shutter actuation

Testing at NASA Glenn - off to a great start!



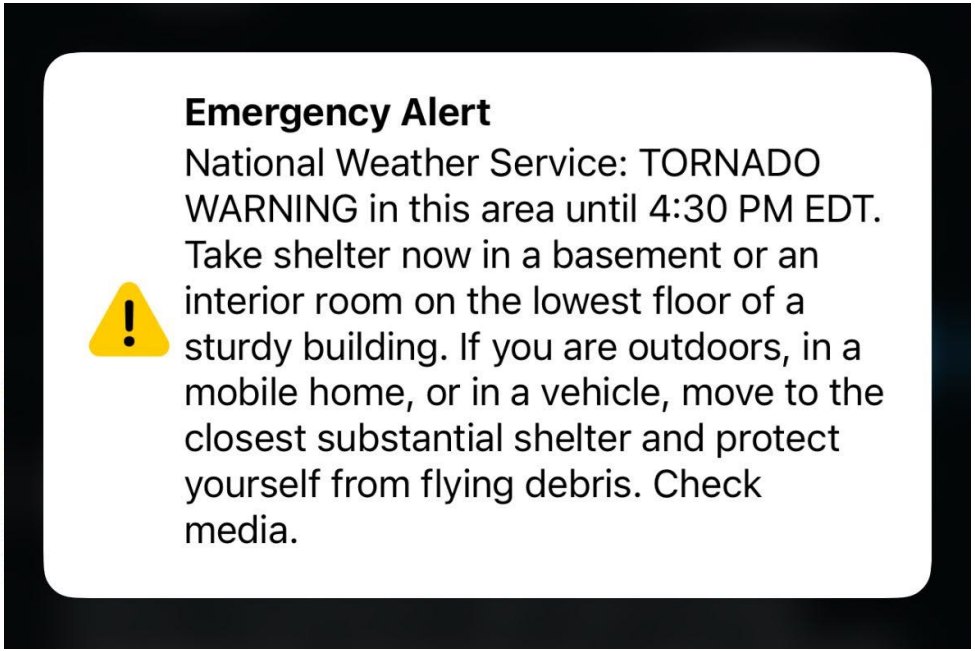


Until…Aug 6

Five EF-1 tornadoes and widespread straight-line wind damage occurred across Northeast Ohio. Over 400,000 residents were left without power, the most significant number since the July 1993 storms. Cuyahoga, Lake, and Geauga Counties were hit especially hard with over half of residents experiencing power outages. Aug 6, 2024

National Weather Service (.gov)
https://www.weather.gov › cle › event_20240806_seve...

August 6, 2024 Severe Winds and Tornadoes



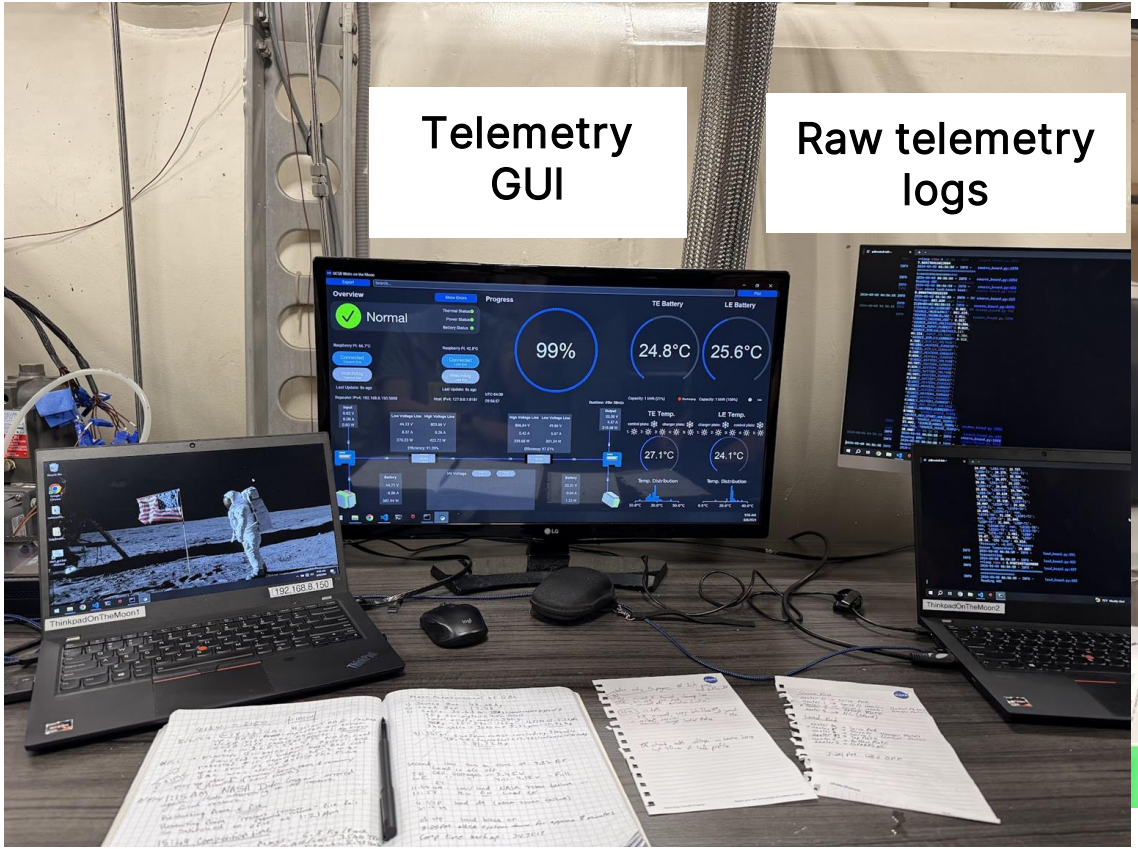
Nevertheless...

Despite having no power at our hotel for the last three days of testing, we fought on, staying with the system overnight.

Not a single system failure on our side!

Custom software was extremely useful in monitoring system health.

Finally...


Telemetry GUI
Raw telemetry logs
Overview
Normal
Progress
99%
TE Battery
24.8°C
LE Battery
25.6°C
TE Temp.
27.1°C
LE Temp.
24.1°C
ThinkpadOnTheMoon1
192.168.8.150
ThinkpadOnTheMoon2


Normal
100%
24.8°C
25.6°C
ThinkpadOnTheMoon1
192.168.8.150

Results – ZERO failures on our side

Lots of fun with wonderful GRC NASA Team

- 100% system uptime
- ~30% SoC remaining on source side ~100% SoC remaining on load side
- ***Despite never testing the full system in a full thermal vacuum system (not available to us), we got it right on the first try!***
- ***We built a small thermal vac (77K) system***
- We carried a >30% energy margin
- →Had we tested a second time…
- In one hour…
- We would have been 13 kg lower in mass!
- →Or ~ 70 kg total mass inc 3 km cable←

Future Development

- Paralleling DC/DC converter modules for more output power (14 kW)
- Series DC/DC converter allows for >2 kV system
- System extensible to >100 kW
- Full superconducting power grid on moon options
- Modularity of system to support a wider range of applications
- Optimizing for terrestrial applications with air cooling
- Simplifying for multimodal operation - DC Microgrid

Tethered Vehicle examples – many more options