National Aeronautics and Space Administration

NASA

Space Technology Mission Directorate
Game Changing Development Program

Jeffrey Csank | Microgrid Definition and Interface Converter for Planetary Surfaces | Annual Program Review | September 10-12, 2024

Overview

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Needs Addressed by Project

Stakeholder (e.g. HLS)	The project and its technology products will impact the overall NASA Artemis program, and will help recommend lunar power grid operating characteristics to ESDMD, STMD, and Industry
Stakeholder	Development of a power interface that supports the phased development and evolution of lunar surface activities based on a notional design for an evolvable, reconfiguration, reliable, and sustainable micro-grid

Project Goals

Goal #1	Develop a strategy for integrating and connecting dissimilar power sources and loads that arrive on the lunar surface over a period of years and can function as a “synergistic-whole”.
Goal #2	Develop a standardized interface for lunar power/load technologies to reduce the overall integration effort and ensure power quality requirements are met

Project Objectives

Objective #1	Document a timeline of power and energy storage needs on the lunar surface based upon NASA information available from Artemis.
Objective #2	Obtain STMD and ESDMD agreement to implement applicable architectures, and coordinate with industry to develop architectures that are universally acceptable to industry.
Objective #3	Develop a model to inform ESDMD lunar surface grid decisions and tradeoffs such as layout (ring, star, blended, distances, etc.), voltages, number of converters and interfaces, etc. Select an evolvable concept layout capable of meeting the identified lunar surface power and energy storage needs.
Objective #4	Design and demonstrate a common interface for connecting sources and loads together and design, develop, test, and demonstrate a Universal Module Interface Converter (UMIC).

Microgrid Definition and Interface Converter for Planetary Surfaces

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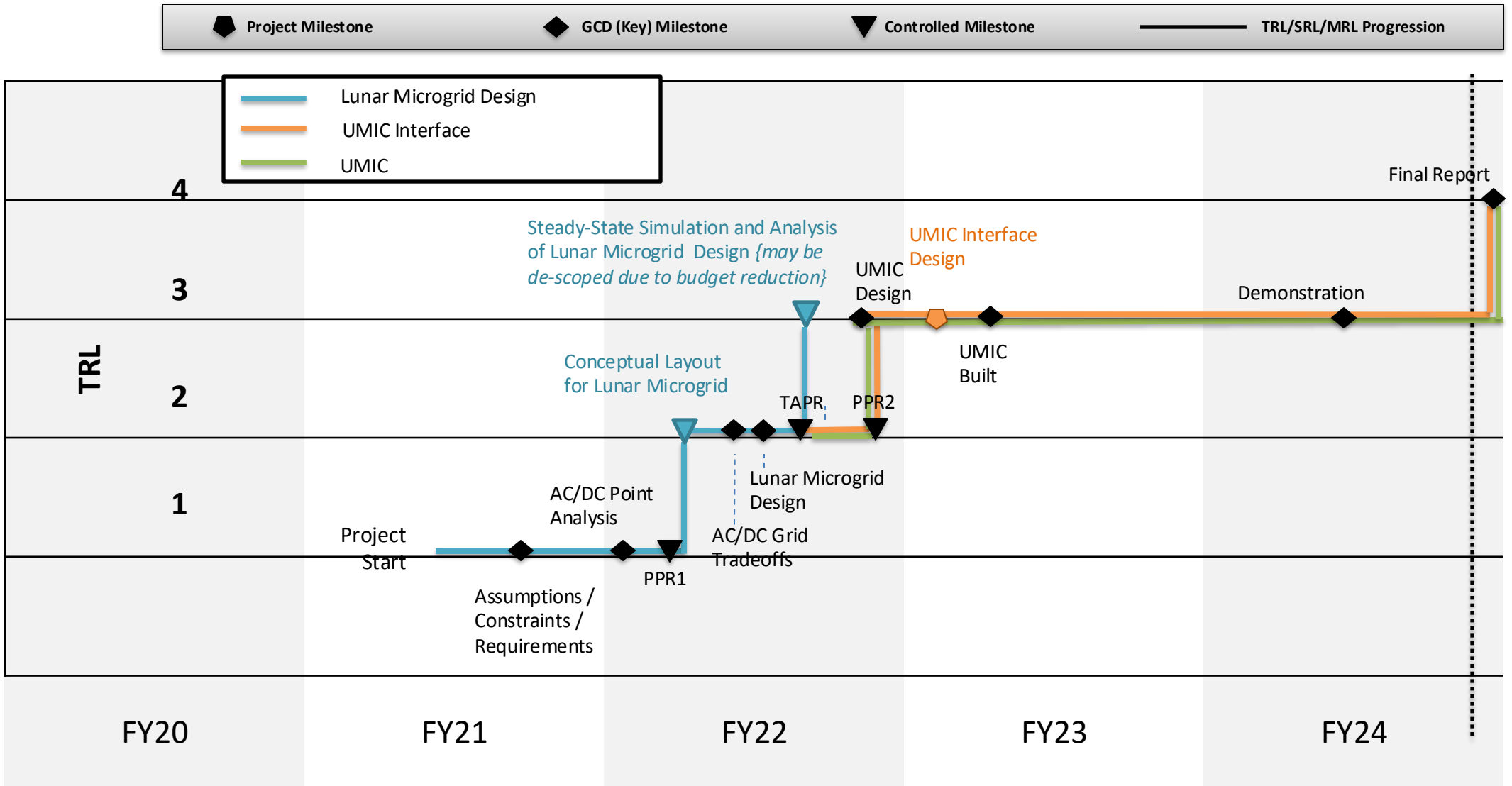

Universal Modular Interface Converter

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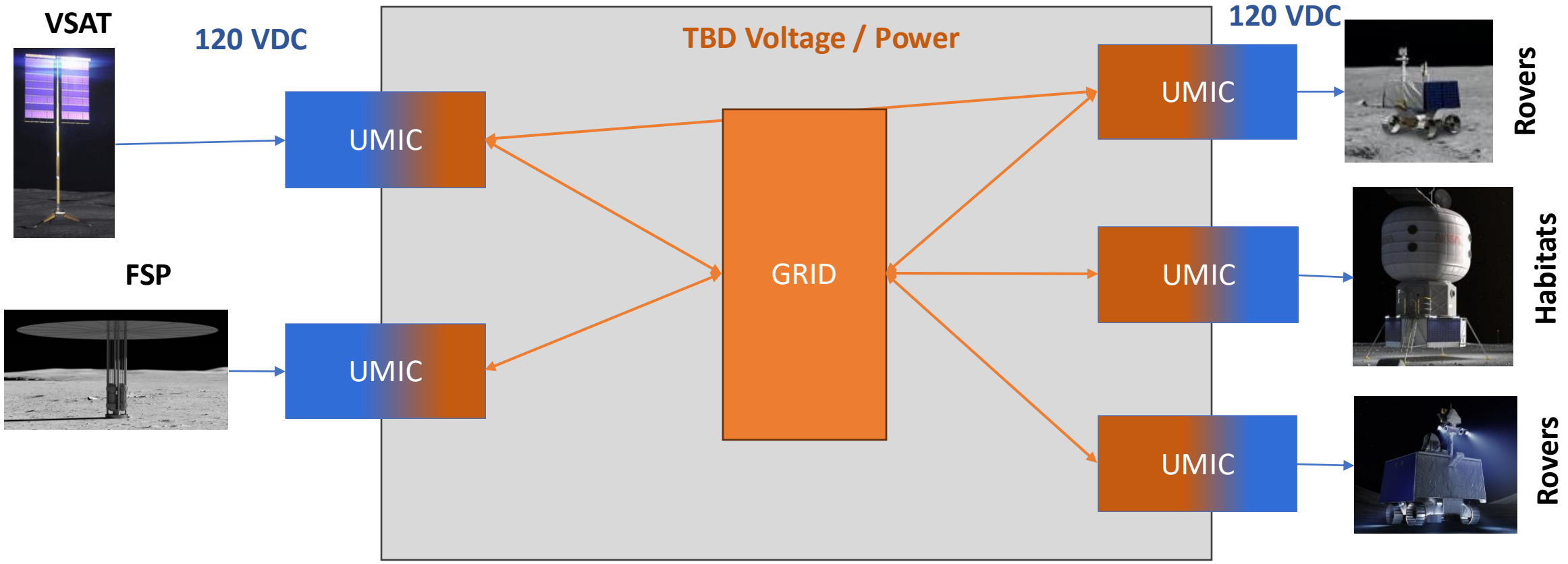

- Currently have standard for 120 VDC and 28 VDC (ISPSIS / HEOMD03-004)
- Power over long-distance will require increase in voltage
- Common interface can be applied to both sources and loads (bi-directional)
- Expand to include larger transmission systems

Universal Modular Interface Converter

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TRL 4 Breadboard Version

- Universal Modular Interface Converter
  - Modular, bi-directional converter
    - Grid side: 3-phase, 3000 VAC, 1000 Hz
    - Load/Source Side: 120 VDC
  - Full rack capable of 10 kW of power (nominal)
    - 12 kW peak
  - Parallelable - can provide more than 10 kW at single location
  - Design goals:
    - >95% efficiency
    - 350 W/kg power density (est. for flight)
  - Capability:
    - Grid forming
    - Grid syncing

Technical Progress and Results

- Successfully demonstrated the operation of the Universal Modular Interface Converter (K12: UMIC Demonstration)
  - Demonstrated converting from 120 VDC to the transmission voltage of 3000 VAC, 1000 Hz, 3-phase and providing 10 kW to an AC load.
  - Demonstrated converting from 3000 VAC, 1000 Hz, 3-phase to 120 VDC and providing 10 kW of power to 120 VDC load.
  - Testing allows UMIC to reach TRL 4.

Technical Progress and Results

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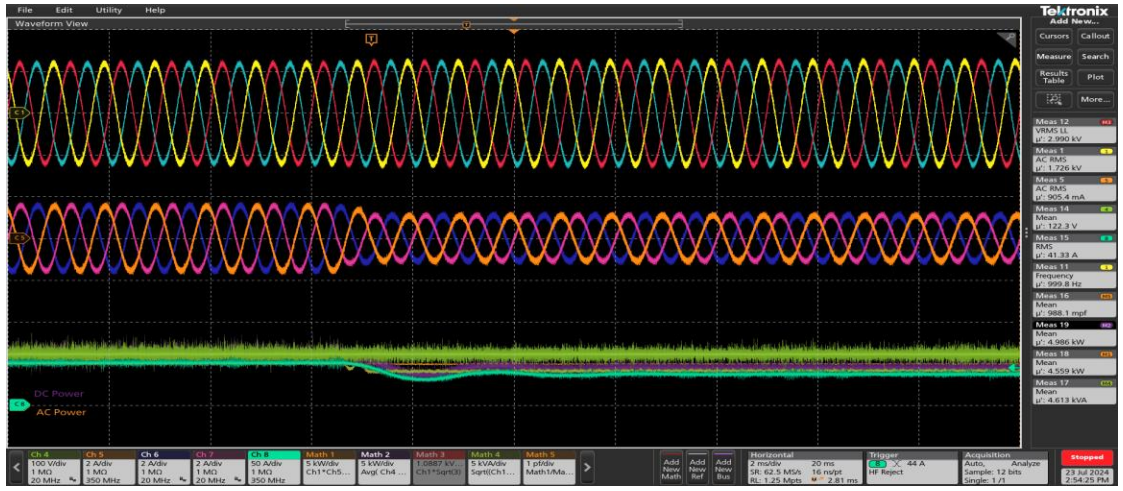
- Performed additional UMIC testing to close the appropriate TBR/TBDs in the UMIC interface definition document.
  - Additional testing allows the UMIC interface to achieve TRL 4.
- Finalized the final report draft

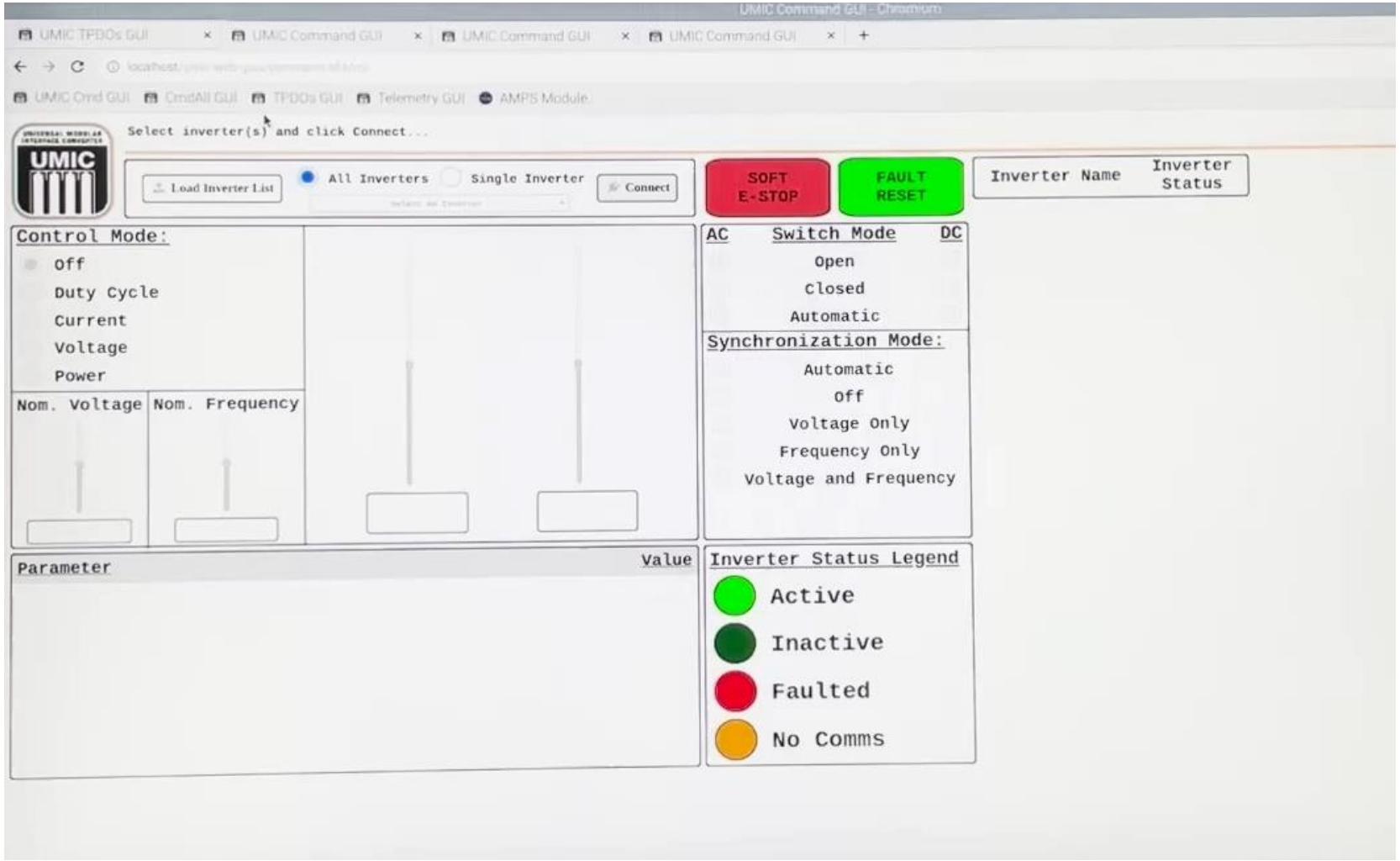


UMIC Load Step Test Data to Close TBRs in Interface Definition Document

UMIC Instrumentation Used For Testing

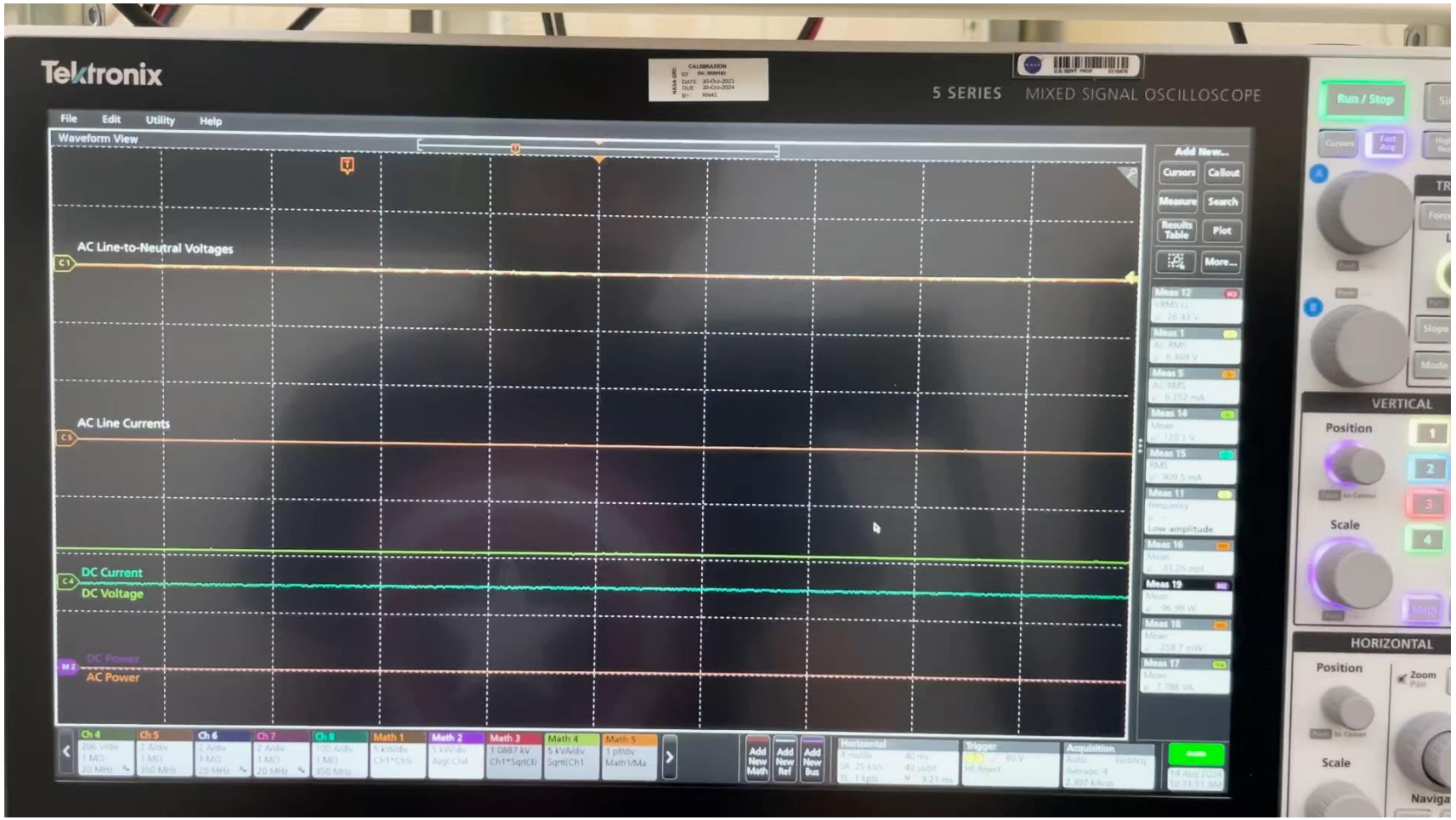
Technical Progress and Results

- Starting dead AC bus with UMIC via GUI
  - Load GUI web page
  - Connect to inverters
  - Close UMIC DC switches
  - Command UMIC to run as voltage source
  - Close UMIC AC switches to provide power to AC bus



Technical Progress and Results

- Footage of power analysis oscilloscope during slow startup of UMIC



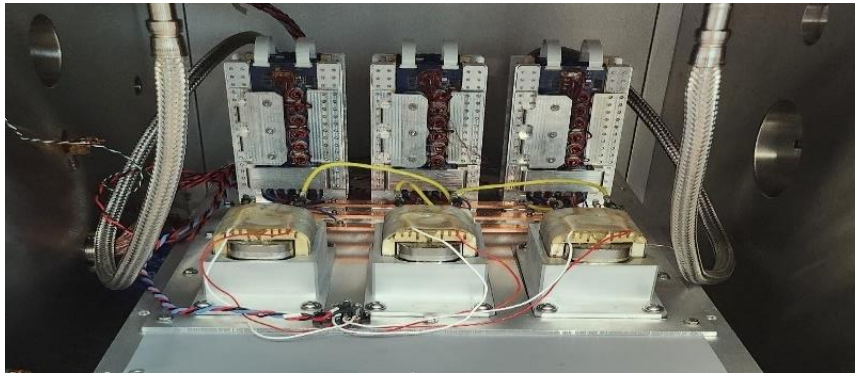
- 3 Phase AC Voltages
- 3 Phase AC Currents
- DC Voltage & Current
- DC Power & AC Power

Transition/Infusion Status

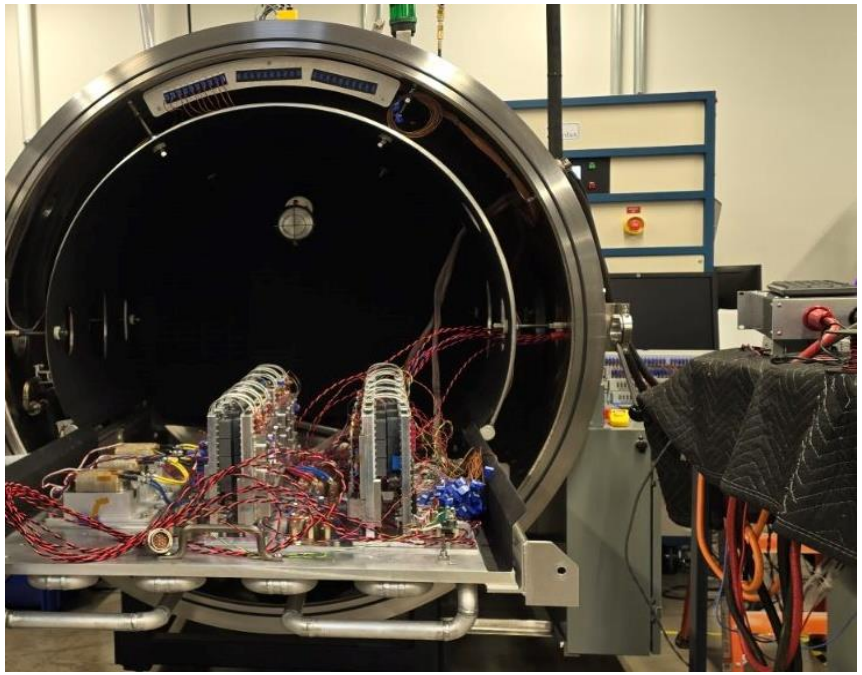
- Mission Infusion
  - ESDMD / Mars Campaign Office / Advanced Modular Power Systems (AMPS)
    - Conceptual grid used for power trade studies helped define collaboration between Advanced Modular Power Systems (AMPS) project and Sandia National Laboratories.
    - MIPS conceptual lunar architecture, trade studies, and UMIC concept presented to ESDMD management. Based on this, Lunar Architecture Team considered the use of a power grid for power distribution.
  - ESDMD / Strategy and Architecture Office / Lunar Architecture Team
    - Presented trade studies results and UMIC development plans for long-distance power transmission.
    - LAT Power members participated in TAPR reviews.
  - ESDMD / M2M / xEVA and Human Surface Mobility
    - Presented trade studies results and UMIC development plans for long-distance power transmission.
    - EHP Power participated in TAPR reviews.
  - STMD / Technology Demonstration Maturation / Fission Surface Power
    - FSP requires transmitting power 1km or more
    - Provided UMIC design information to the internal GRC FSP team to enable the design of a custom interface for the UMIC to exchange power with FSP.

Transition/Infusion Status

- Partnerships & Commercial Transition
  - **Astrobotic VSAT Contract**
    - GRC to build and deliver a 10kW UMIC with power electronics redesigned with flight-like thermal design
    - Astrobotic using project to test (TVAC) UMIC and assess options to integrate UMIC into their future VSAT design
    - Completed
      - Redesigned 1kW inverter/rectifier modules for thermal environment.
      - 1kW TVAC test at GRC (July 2024)
      - Delivered 10kW UMIC to Astrobotic and TVAC tested at Astrobotic (August 2024).



GRC internal TVAC test of inverter/rectifiers (VF-18)

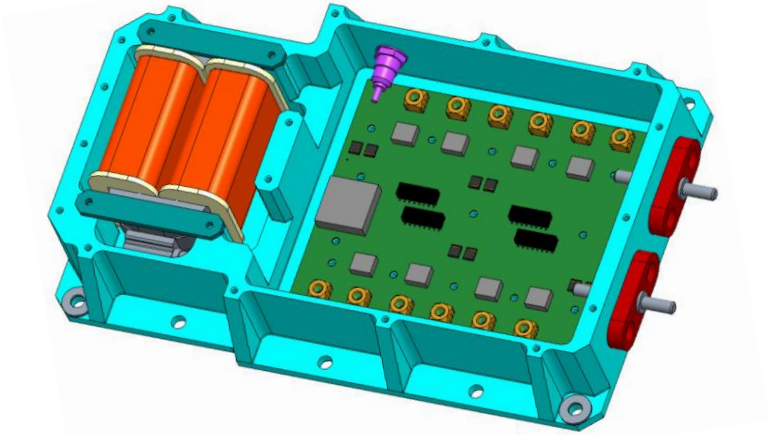


10 kW test article in Astrobotic TVAC chamber

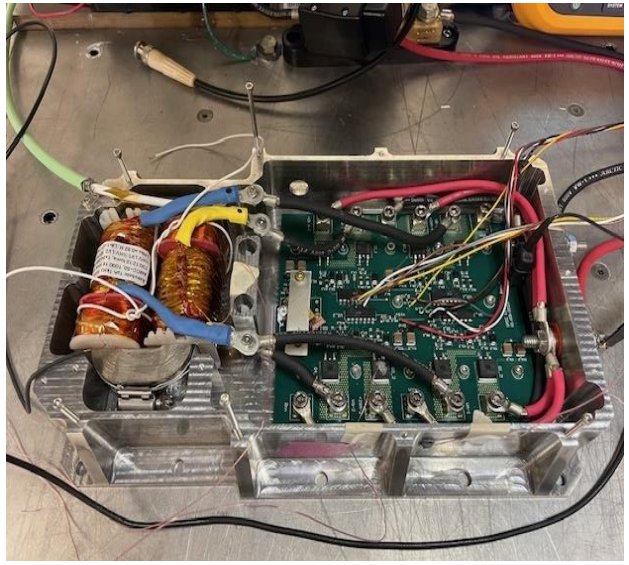
Transition/Infusion Status

- Partnerships & Commercial Transition

  - **Astrobotic Luna-Grid Lite (LGL) Tipping Point (Reimbursable Space Act Agreement)**
    - Astrobotic awarded TP to test deliver and test lunar cable and rover cart.
      - Astrobotic would like to include a single phase 1kW version of UMIC
    - GRC to build and deliver TRL 6 1kW inverter/rectifier and transformer (TVAC and Shock & Vibe)
      - Redesign of 1kW inverter/rectifier module
      - Support Astrobotic design and build of Engineering Model
      - Support Astrobotic design and build of Flight Model



LGL UMIC Breadboard CAD Rendering



LGL UMIC Breadboard on Bench

Transition/Infusion Status

- Partnerships & Commercial Transition

  - **Lockheed Martin Corporation (LMCO) Non-Reimbursable Space Act Agreement**
    - LMCO to provide frequency trade study addressing interaction with lunar regolith and attenuation associated with long cables
    - GRC to provide TRL 4 10 kW UMIC (UMIC 003) to LMCO for testing
    - LMCO to determine if UMIC can be integrated into their lunar power architecture / power node design

  - **Blue Origin Alchemist Tipping Point (Reimbursable Space Act Agreement)**
    - Blue Origin to collaborate with GRC on the design of a power system for Blue Origin's in-situ resource utilization plant systems. This would include:
      - Defining interfaces, requirements, etc.
      - Establishing a baseline power system architecture to meet the needs of the ISRU plant
    - GRC currently finalizing a RSAA Annex with Blue Origin to Space Act Umbrella Agreement No. KCA-4774.
      - Support Blue Origin with the development of a preliminary High-Power Spacecraft and Lunar Surface Power Architecture
      - Developing a power transmission model and performing trade studies to evaluate the performance of a grid/power transmission system
      - Applying GRC PMAD related technologies, such as the Universal Modular Interface Converter and AMPS Autonomous Power Controller

Microgrid Definition and Interface Converter for Planetary Surfaces
Assessment Summary

Timer

Project Name	Performance				Comments
	C	S	T	P	
Annual					Technical – Power quality issues discovered and mitigated Cost – Project within FY24 Guidelines Schedule – Some delays due to Safety review and recommendations, and power quality issues Programmatic – CR approved to move Controlled Milestone Final Report and Project End date to 9/6 and 9/30, respectively

	Oct	Nov	Dec	Jan	Feb	MYR	Apr	May	Jun	Jul	Aug	APR
C												
S												
T												
P												

Technical – Encountered recirculating currents between the inverter modules in the UMIC. Developed and tested UMIC rack sync bus to mitigate recirculating currents between inverters.
Schedule – Delay in High Voltage tests due to Safety review recommendations. Required e-Stops, tie-in to Facilities, and changes to installation method of wiring and busbars to mitigate High Voltage corona issues. Additional Power Quality issues created delays that was mitigated by the development of the sync bus.