Universal Modular Interface Converter

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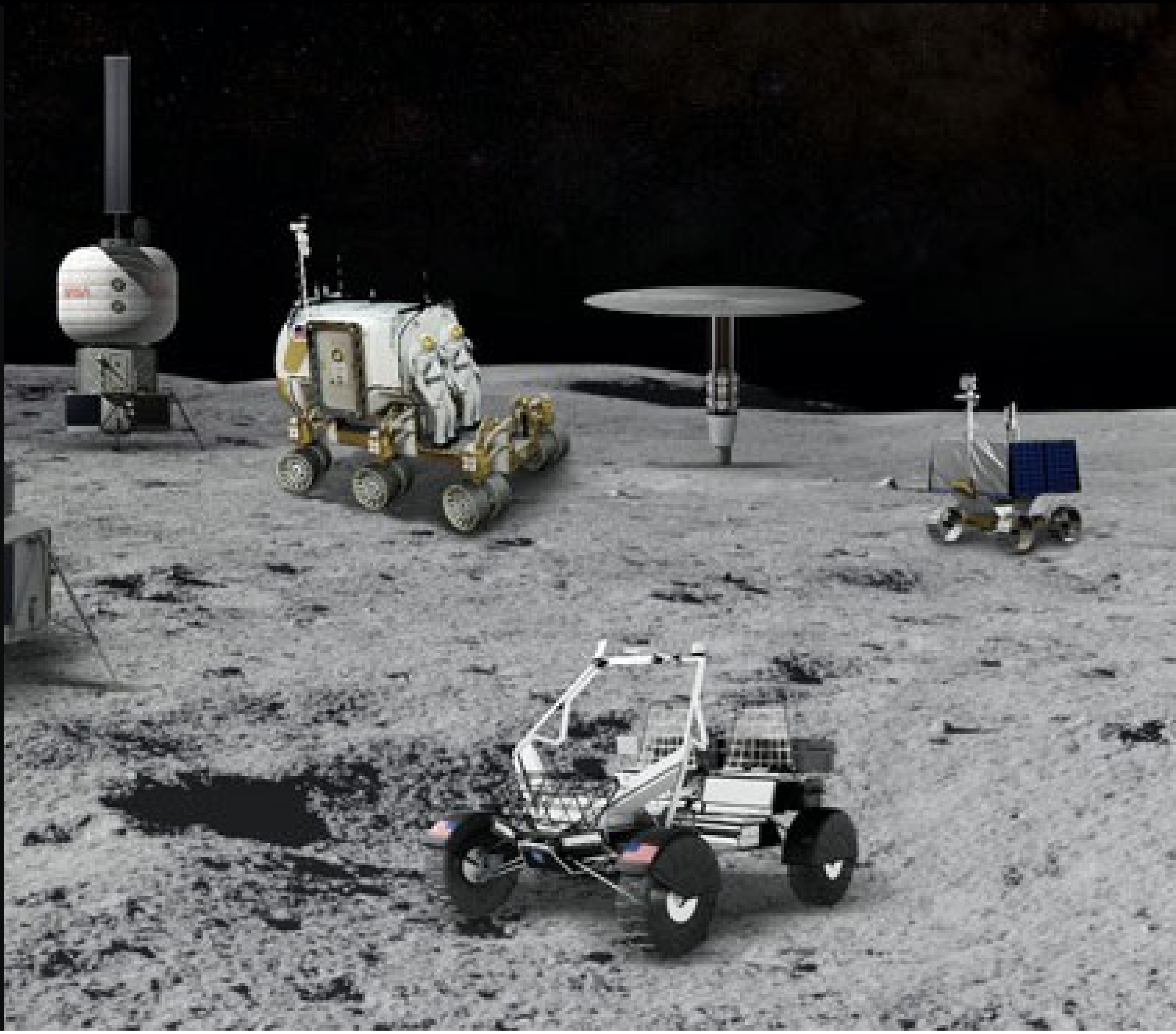


The Need for Universal Lunar Surface Power

- **Lunar surface operations will grow and expand**
  - Power demands will exceed elements capability - Self sufficient power is not feasible
  - Systems will have to be integrated together or to a power grid (shared access)
- **Power over long-distance**
  - Driven by minimum safe landing distance and radiation stand off (1km+)
  - Needed for power in permanently shadowed regions (PSR)
- **Dissimilar power sources**
  - Increase power availability – provide power during longer eclipse periods
  - Contingency scenarios - Provide needed redundancy and reliability

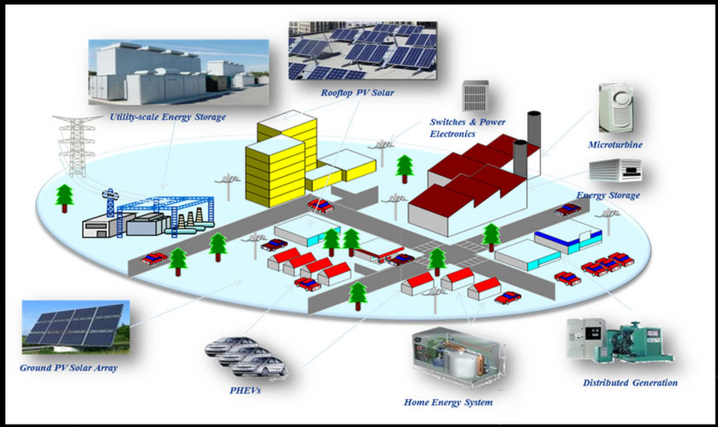
Microgrid Definition and Interface Converter for Planetary Surfaces (MIPS)

- **Space Technology Mission Directorate (STMD)**
  - Game Changing Development (GCD) Program

- **Project goal is to develop technology to provide universal access to power**
  - Define Lunar Power System Architecture
    - Power type and voltage level
    - Power strategy / CONOPS
  - Develop and Demonstrate Converter
    - Universal Modular Interface Converter (UMIC)
    - Define interface to help guide standards and future technology development efforts

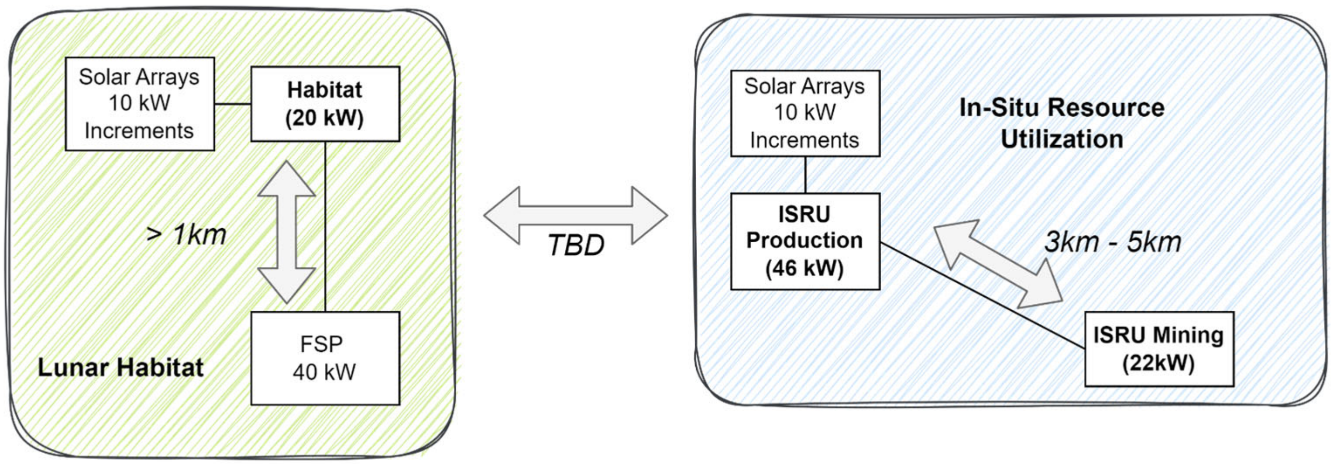
Lunar Power Grid

- **Benefits of a power grid**
  - Flexibility, evolvability, and reconfiguration
  - Optimal dispatch of power sources and energy storage to service loads & enhance reliability
  - Systematic integration of new sources and loads
  - **Common grid interface (commonality)**
  - Allows for the deployment of future loads that do not need to carry their own power generation



Lunar Power System Architecture

Baseline Architecture Design Requirements



Power Sources:

Solar Arrays
- Vertical Solar Array Technologies (VSAT)
- 10 kW increments
- 120 VDC Source

Fission Surface Power (FSP)
- 40 kW Power
- Voltage TBD (AC)
- Must be located more than 1km from other lunar elements

Lunar Elements (Loads):

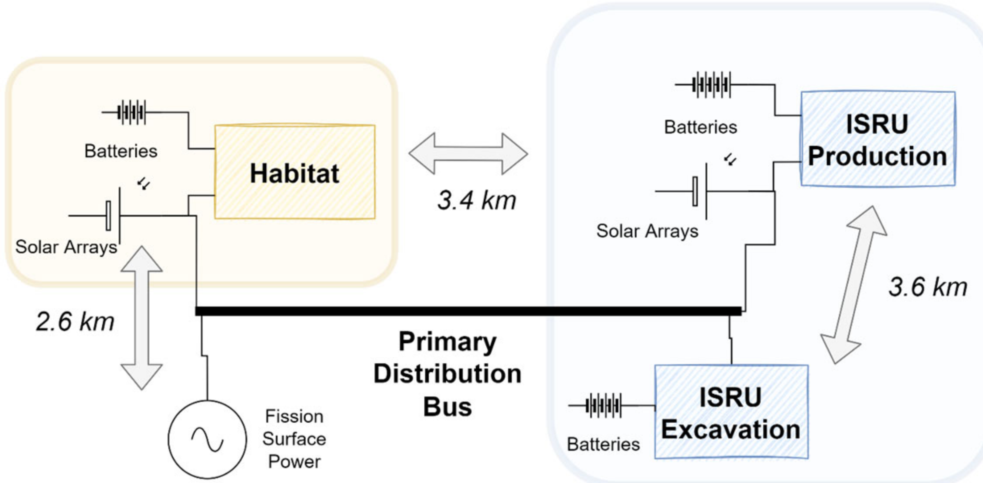
Surface Habitat
- 20 kW during habitation (must be during insolation)
- 2 kW during eclipse and non-habitation

In-Situ Resource Utilization (ISRU)
- ISRU processing - 46 kW insolation / 9 kW eclipse
  - Located on crater rim (in the sun)
- Excavation - 22 kW insolation / 4 kW eclipse
  - Located in permanently shadowed regions (water-ice)
  - About 3km – 5km from processing facility

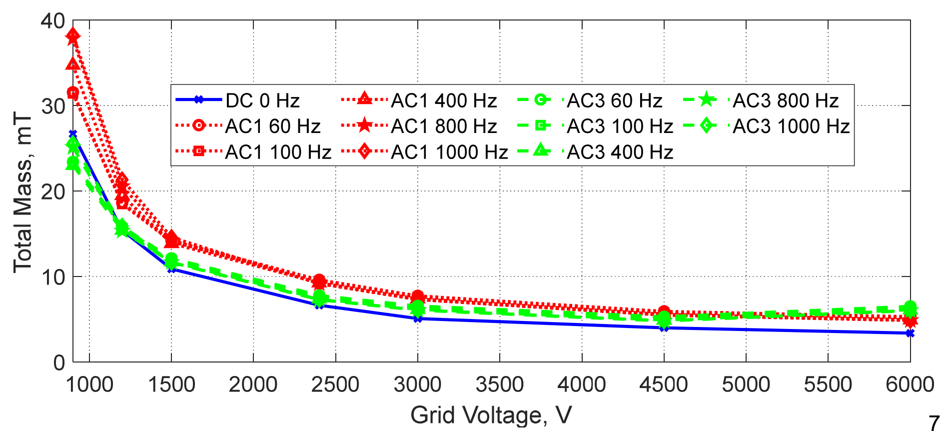
Notional Reference Artemis Base Camp Microgrid

- **Trade studies focused on primary power distribution system (transmission)**
  - Architecture (radial, ring, mesh)
  - Power type (AC vs DC)
  - Voltage: (600V – 6 kV)
  - Data contains estimated mass of converters + cables
- **Results**
  - Increasing voltage decreases mass
  - AC vs DC at a single voltage is marginal
    - Especially higher voltages
  - Technology limitations need to considered
    - Max DC: 1.5 kV
      - Rad hard limitations
    - Max AC: none known

Recommendation: 3kVAC, 3-phase, 1000 Hz



Radial Architecture



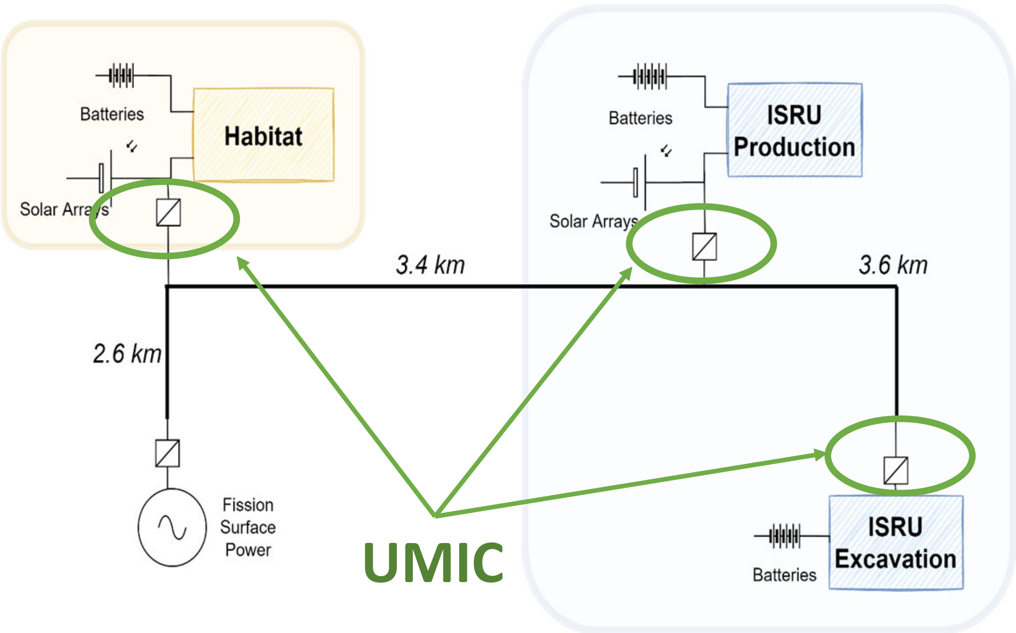
Universal Modular Interface Converter

Universal Modular Interface Converter for a Lunar Surface Grid

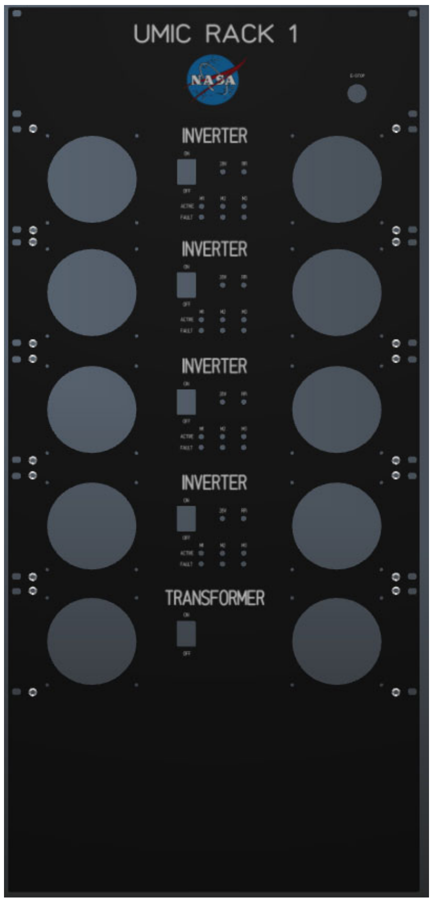
- **Lunar grid can provide key benefits to users of lunar surface power system**
  - Power sharing for improved power reliability/availability
    - FSP power available after 1 year demo
    - Reduce overall energy storage mass by providing night-time power (FSP)
  - Can connect new assets that do not carry their own power

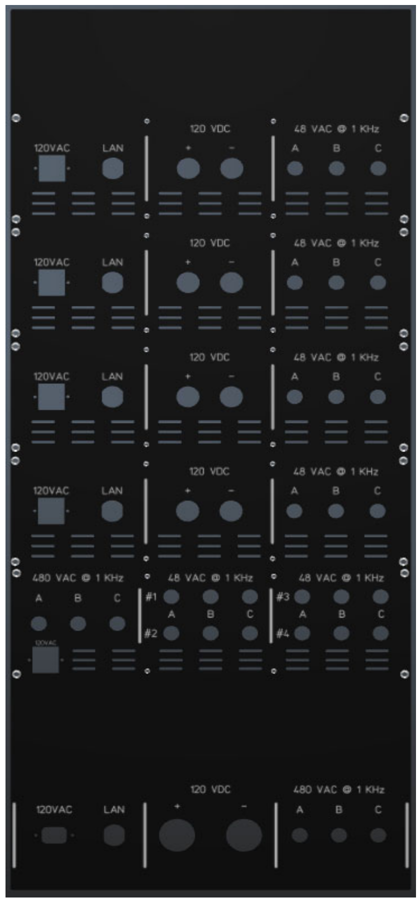
- **The UMIC can connect lunar assets to the grid**
  - Power sources (solar arrays, FSP)
  - Energy storage (batteries, fuel cells)
  - Loads

- **Can be standalone product <u>or</u> integrated into other source or load equipment**



Universal Modular Interface Converter Overview

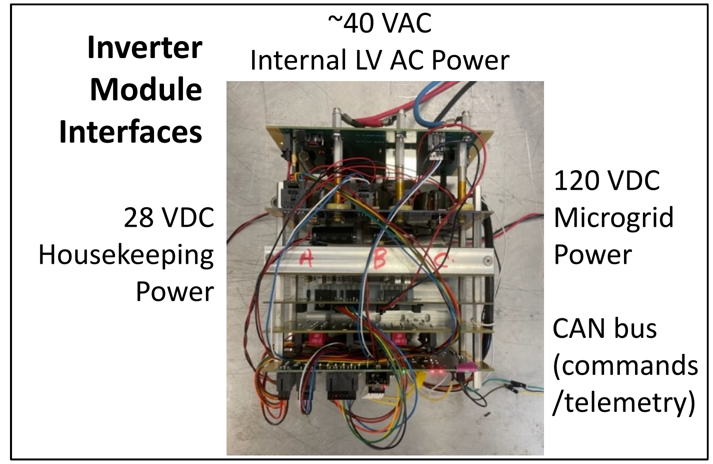


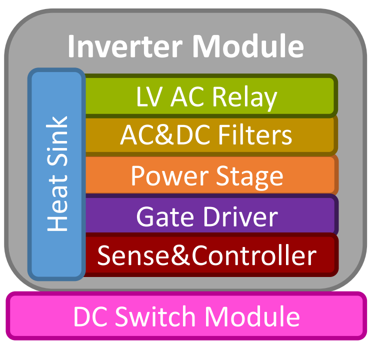


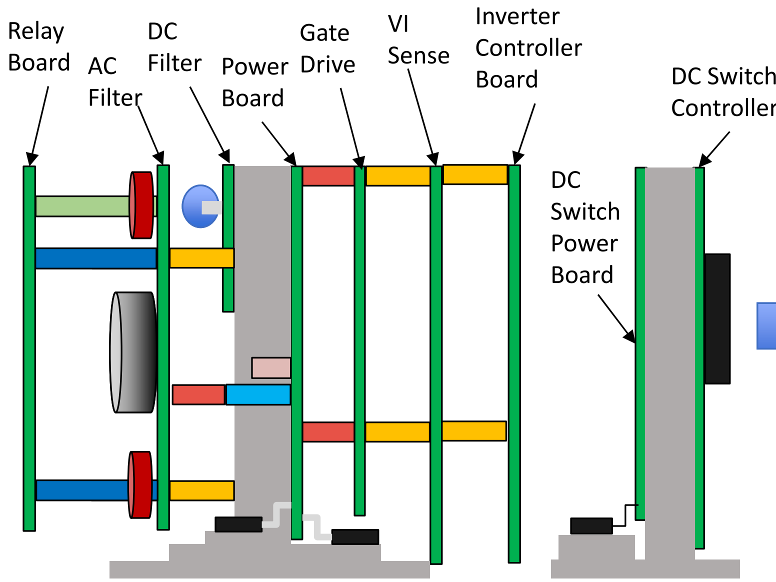
- **Universal Modular Interface Converter**
  - Modular, bi-directional converter
    - Grid side: 3-phase, 3000 VAC, 1000 Hz
    - Load/Source Side: 120 VDC
  - Full rack capable of 10 kW of power (nominal)
    - 12 kW peak
  - Parallelable - can provide more than 10 kW at single location
  - Design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

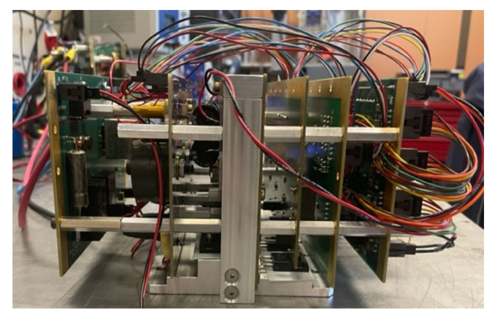
UMIC 1 kW Modular Power Electronics Details

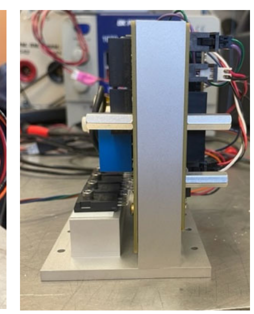
- **1 kW Inverter Module plus 1 kW DC Switch Module**
  - **Inverter**: Converts 120 VDC microgrid bus to UMIC internal low voltage 40 VAC bus
    - Includes filters, power control logic, AC isolation
    - Consists of 5 main subsystems in a stacked card form factor
  - **DC Switch**: Provides DC-side current limiting & isolation capability











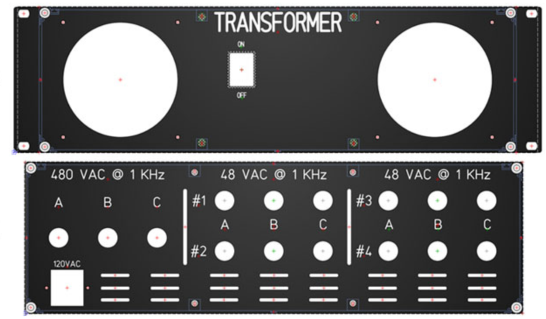
UMIC Transformer Details

- **Transformer chassis to include all transformers needed at a given site**
  - May shrink or grow based on site power needs

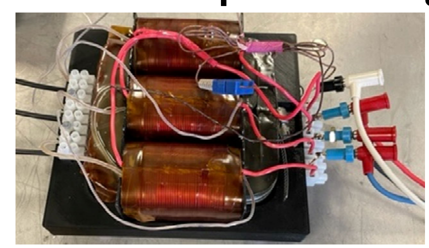
- **Modular (1 kVA) transformers design (both single and 3-phase types)**
  - 10x 1 kVA three phase transformers (10 kVA total)
- **Centralized transformer design (both single-phase type only)**
  - 3x 3.3 kVA single phase transformers (10 kVA total)

TRANSFORMER FRONT

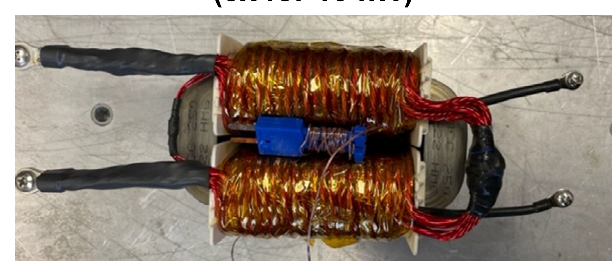
TRANSFORMER REAR



NASA 1 kVA 3-phase design



3.3 kVA single-phase design
(3x for 10 kW)

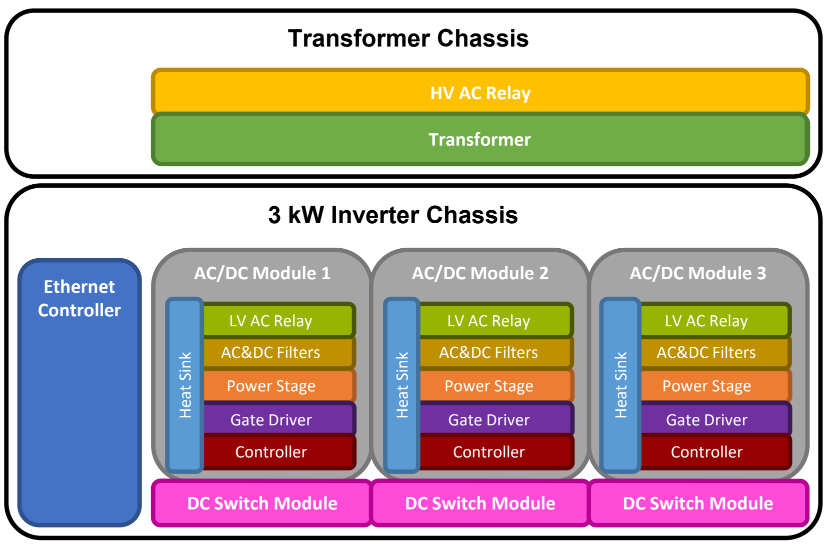


3 kW UMIC Initial Breadboard Chassis Implementation

- **Common 19" rack form factor selected for packaging**
  - Volume enough for 3 kW of inverter modules
  - 3-10 kW of transformers (scalable to other systems/loads)

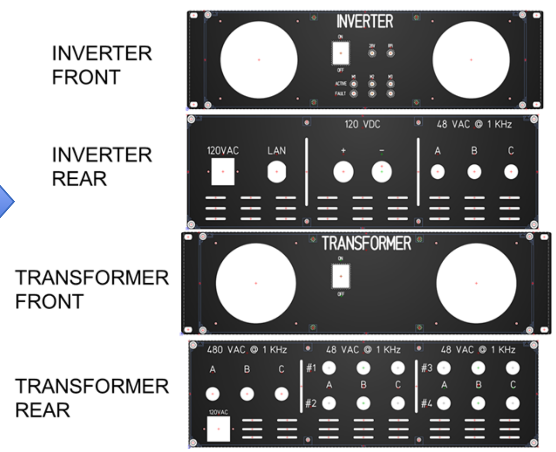
Conceptual Breadboard Chassis Design

3 kVAC, 1000 Hz, 3-phase

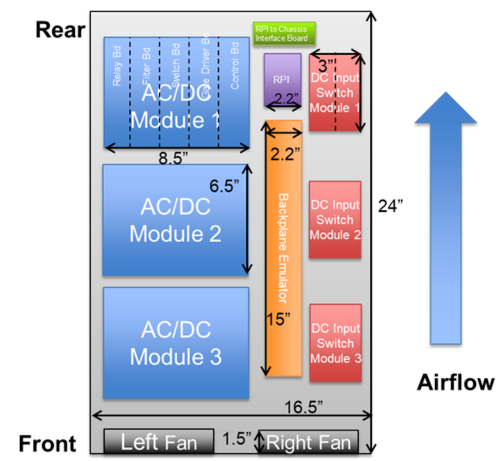


120 VDC

Front and Rear Panels



Chassis Top View



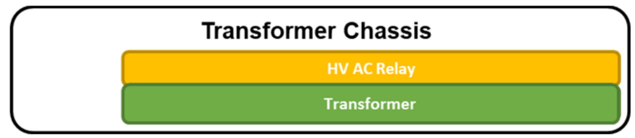
3 kW UMIC Rack

3 kW UMIC Rack

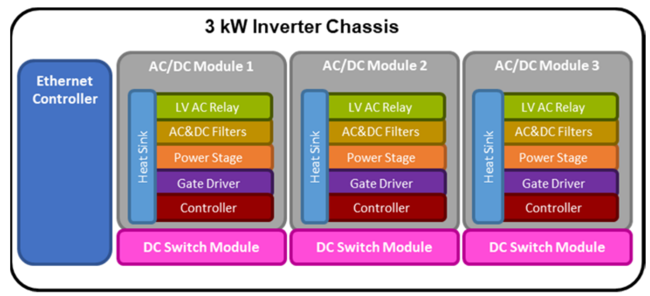
2 kVA continuous with margin, 3 kVA peak

3 kW UMIC Rack

- 1x Transformer Chassis (3 kVA)



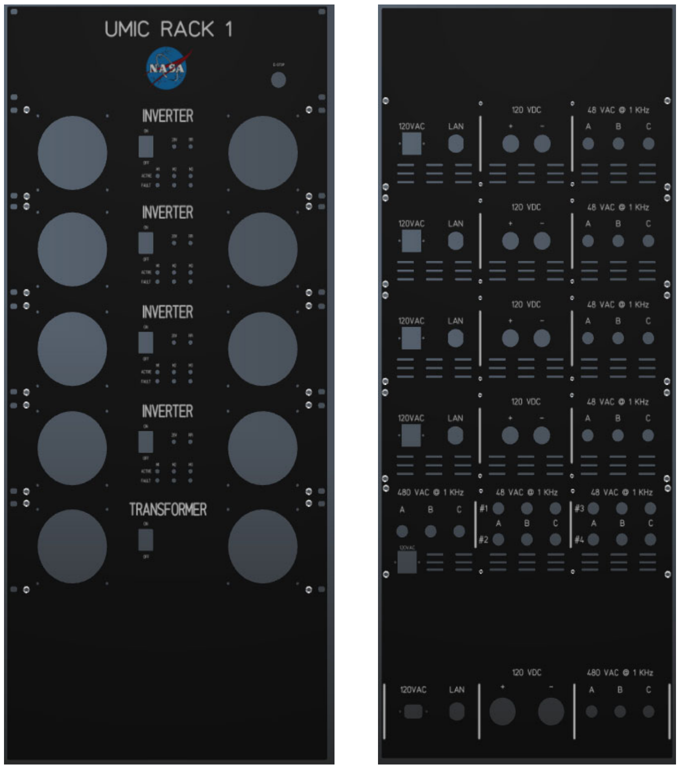
- 1x Inverter Chassis (3 kW each)



- Interface Rear Panel
  - 120 VDC
  - 3 kV AC
  - Ethernet/LAN
  - 120 VAC mains power (housekeeping/fans)

10 kW UMIC Rack

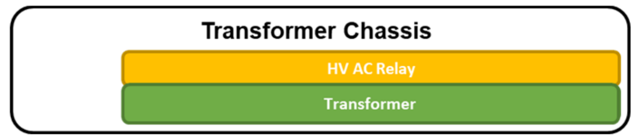
10 kW UMIC Rack



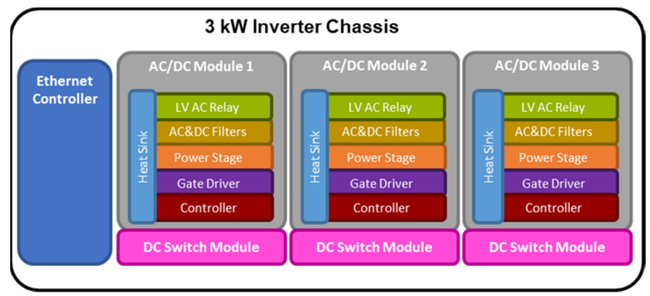
10 kVA continuous with margin, 12 kVA peak

10 kW UMIC Rack

- 1x Transformer Chassis (10 kVA)



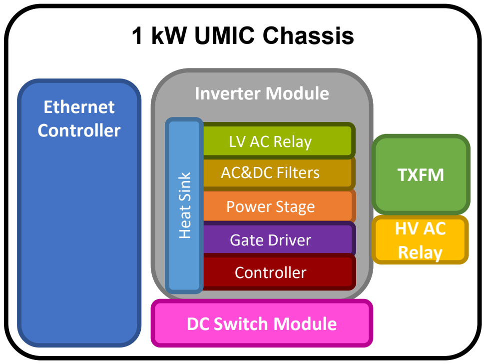
- 4x Inverter Chassis (3 kW each)

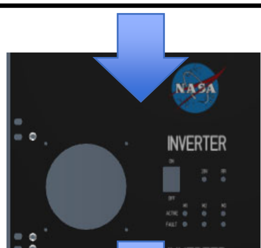


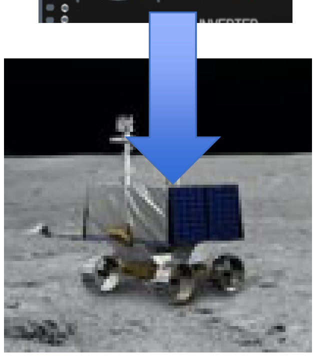
- Interface Rear Panel
  - 120 VDC
  - 3 kV AC
  - Ethernet/LAN
  - 120 VAC mains power (housekeeping/fans)

UMIC Scales to Application

1 kW UMIC



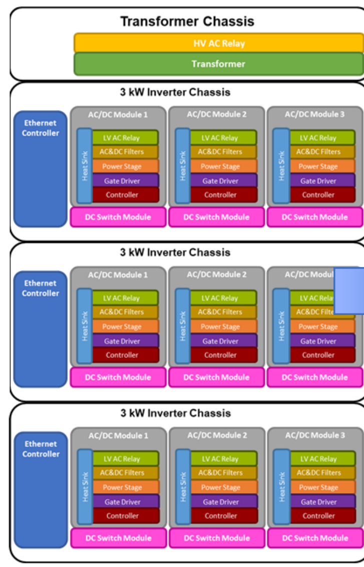


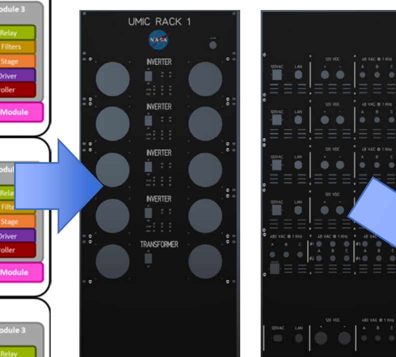


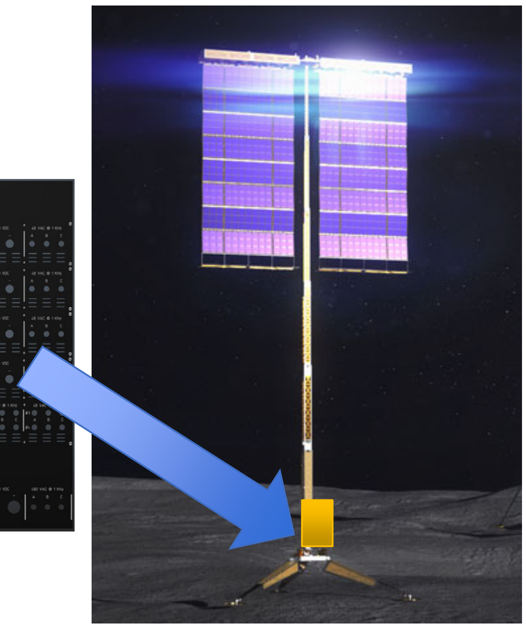
Add modules to go from

Low Power to High Power

10 kW UMIC







Use cases of UMIC / potential applications

UMIC can serve as interface converter between variety of space power assets

AC	DC
• Point-to-point AC transmission system • AC power grid • AC loads – Motors – Heaters	• Stationary DC loads – Habitat – In Situ Resource Utilization (ISRU) • Rover or rover charger • Power plant – Solar array – Fission Surface Power (rectified DC interface) • Energy storage element – Battery – Regenerative fuel cell (RFC)

Remaining Milestones

MIPS Milestones Remaining	Date	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23	Dec-23	Jan-24	Feb-24	Mar-24	Apr-24
First Breadboard UMIC Rack Build & Delivery to ASPIRE Lab	***7/15/2023***										
Single 10 kW UMIC Demonstration	**9/29/2023**										
Second Breadboard Rack Build & Delivery to ASPIRE Lab	***10/31/2023***										
Multi-UMIC Demo	***12/31/2023***										
UMIC Documentation	**12/15/2023**										
MIPS Final Report	**1/29/2024**										

Thank you