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Lunar Surface Power Systems Architecture Vision

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NASA'S MOON TO MARS OBJECTIVES

- **Lunar Infrastructure Goals:**
  - ***LI-1: "Develop an incremental lunar power generation and distribution system that is evolvable to support continuous robotic / human operation and is capable of scaling to global power utilization and industrial power levels"***

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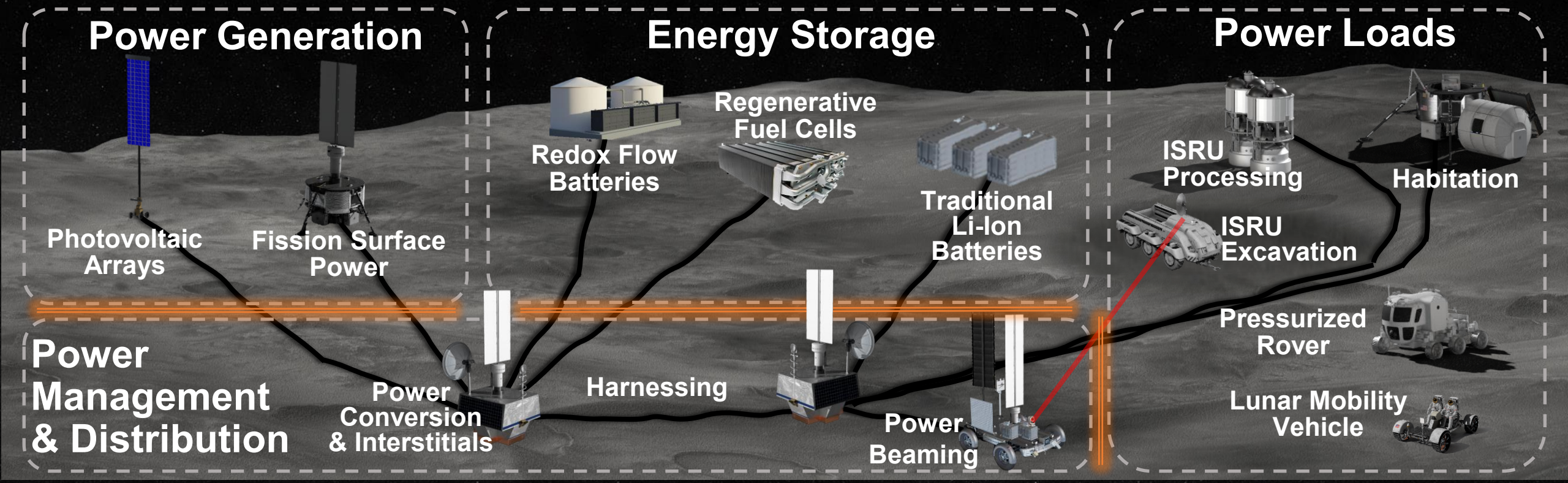
DECOMPOSING THE LUNAR POWER GRID



Key Interfaces

Power Generation
Energy Storage
Power Loads
} ***Element Endpoints***

Infrastructure { ***Power Management & Distribution (PMAD)***

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CORE TENETS OF LUNAR POWER ARCHITECTURE

- **Adoption of Open Systems Architecture (OSA) design principles enables sustainable architectures**
- **A sustainable Lunar surface power grid architecture should be *effective, efficient,* and *resilient***

Effective:

- Generation & storage elements meet steady-state / dynamic load demands
- Power demand successfully delivered to loads
- Loads managed within the performance capability of the grid

Efficient:

- System cost per kWh minimized over indefinite system life
- Maintenance & operational burdens minimized

Resilient:

- Grid operates through faults / functional re-configurations
- Reliability & fault responses consistent with power load operational tolerances

System design focus will be on optimizing core system design tenets and enabling a sustainable architecture

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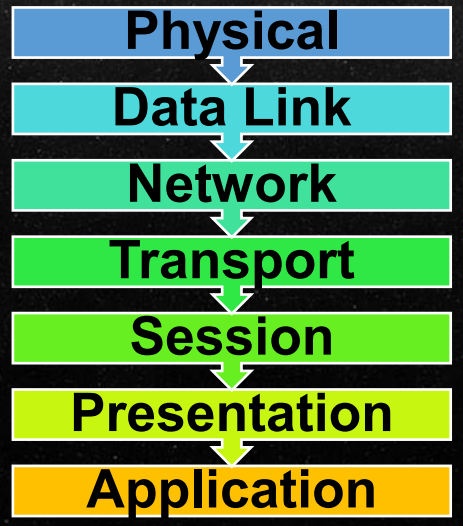
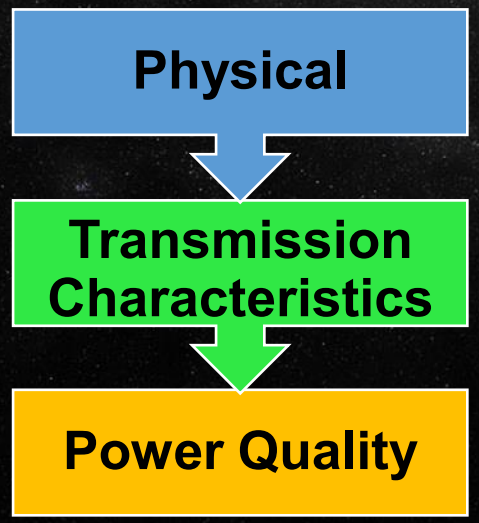
INTEROPERABILITY & MODULARITY

- **Interoperability:** Ability to successfully interact with another interface and perform required functions
- **Modularity:** Ability to be replaced by a similar module to supplant a similar function and be integrated into other systems
- Both are only relevant in the context of defined system interfaces

Open Systems Interconnection (OSI) Model for Networked Communications:



Conceptual Lunar Surface Power Systems Network Model:



- Connector & pin-out families
- Mate / de-mate frequency
- Robotic / crew handling

- Interface voltages
- Waveform / frequency
- Stability & reliability

- Noise / aperiodic surges
- Emissions & susceptibility
- E3 considerations

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ARCHITECTURAL FLEXIBILITY & SCALABILITY

Architectural Flexibility

- Ability of the system to persist over time (indefinitely)
- Ability of the system to satisfy a dynamic range of both loading configurations and geographies
- Long-term resilience of the core system design

Operational Scalability

- Ability of the system to scale significantly in power generation or energy storage
- Ability of the system to scale in peak or average delivered power
- Ability of the system to grow in geographic coverage

Architecture design focus on flexible & scalable architectures enable evolution with minimal rework, redesign, and recourse

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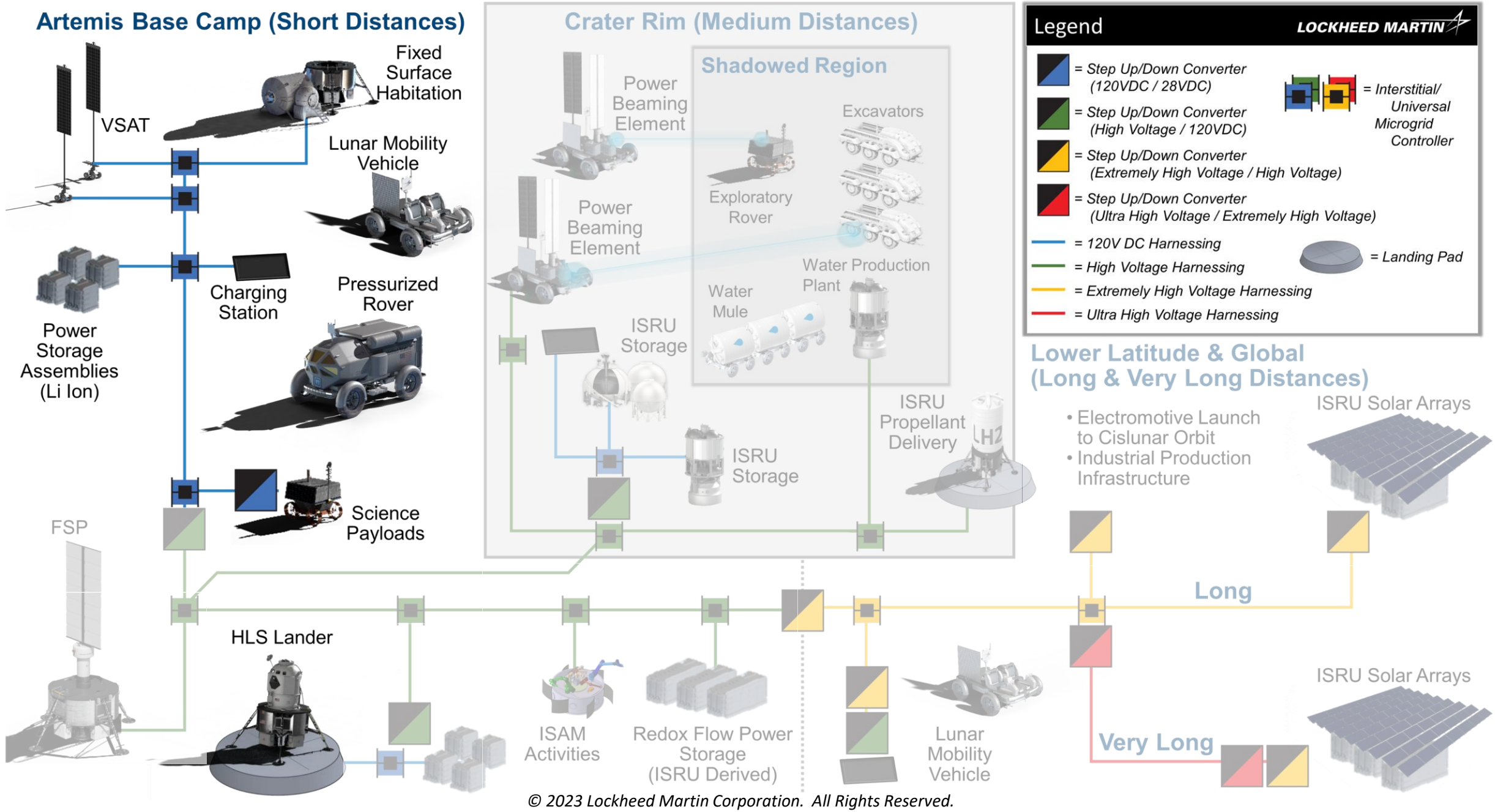
COLLABORATIVE POWER ARCHITECTURE VISION



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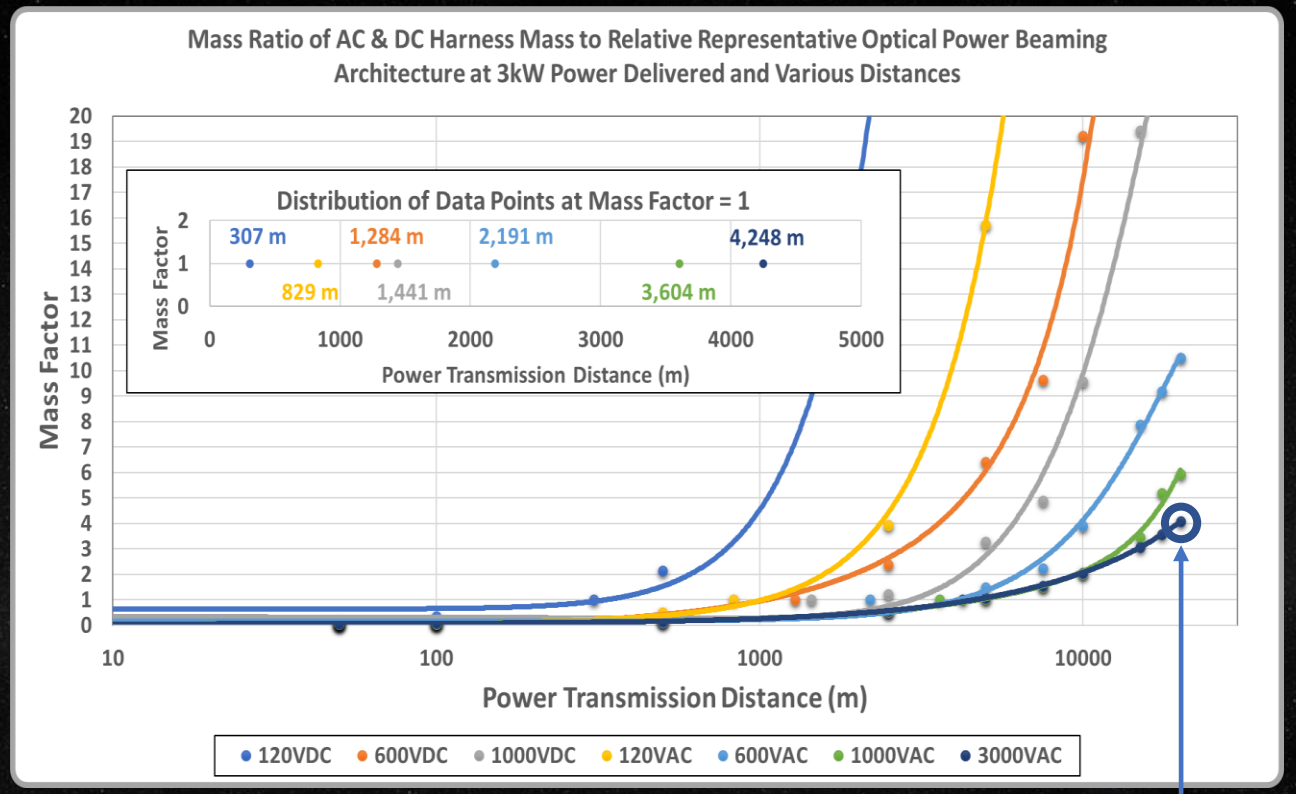
ONGOING LUNAR SURFACE POWER TRADES



Optical power distribution architectures mass is ~4x less than a 3kVAC system for delivery of 3kW to a distance of 20km

Data can be leveraged to compare costs of wired and wireless power distribution designs:

1. Cost metrics of the relative system masses ($/kg)
2. Power generation costs as they scale with each distribution approach ($/kW)
3. Account for operational & deployment costs

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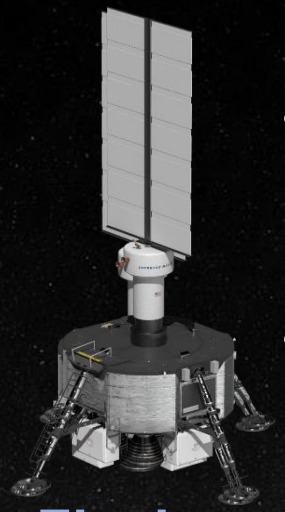
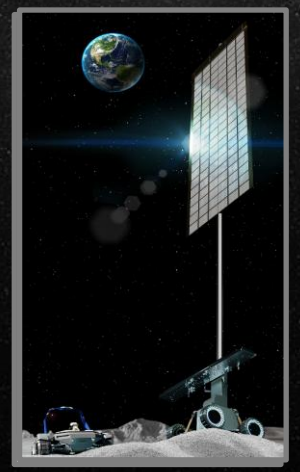
LUNAR SURFACE POWER PORTFOLIO



Fission Surface Power (FSP)

- >40kW$_e$ of continuous power via a direct Brayton power conversion system and a monolithic core
- Reactor design is highly scalable, capable of increasing power by orders of magnitude



Vertical Solar Array (VSAT)

- 10kW$_e$ of mobile power, lifetime of 10 years
- Solar array design is scalable up to 5x existing design implementation



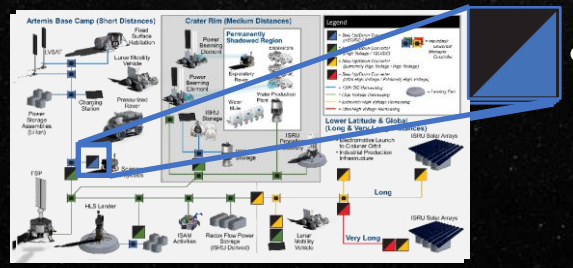
Lunar Mobility Vehicle (LMV)

- Mobility, payload capacity, and mechanisms enable power infrastructure installation and integration



GridStar® Redox Flow Batteries

- Lunar adaptation of this battery design is suited for long-duration, large-capacity storage applications



PMAD Development

- Bidirectional, GaN based 120V/28V DC-DC converter, in addition to other PMAD technologies

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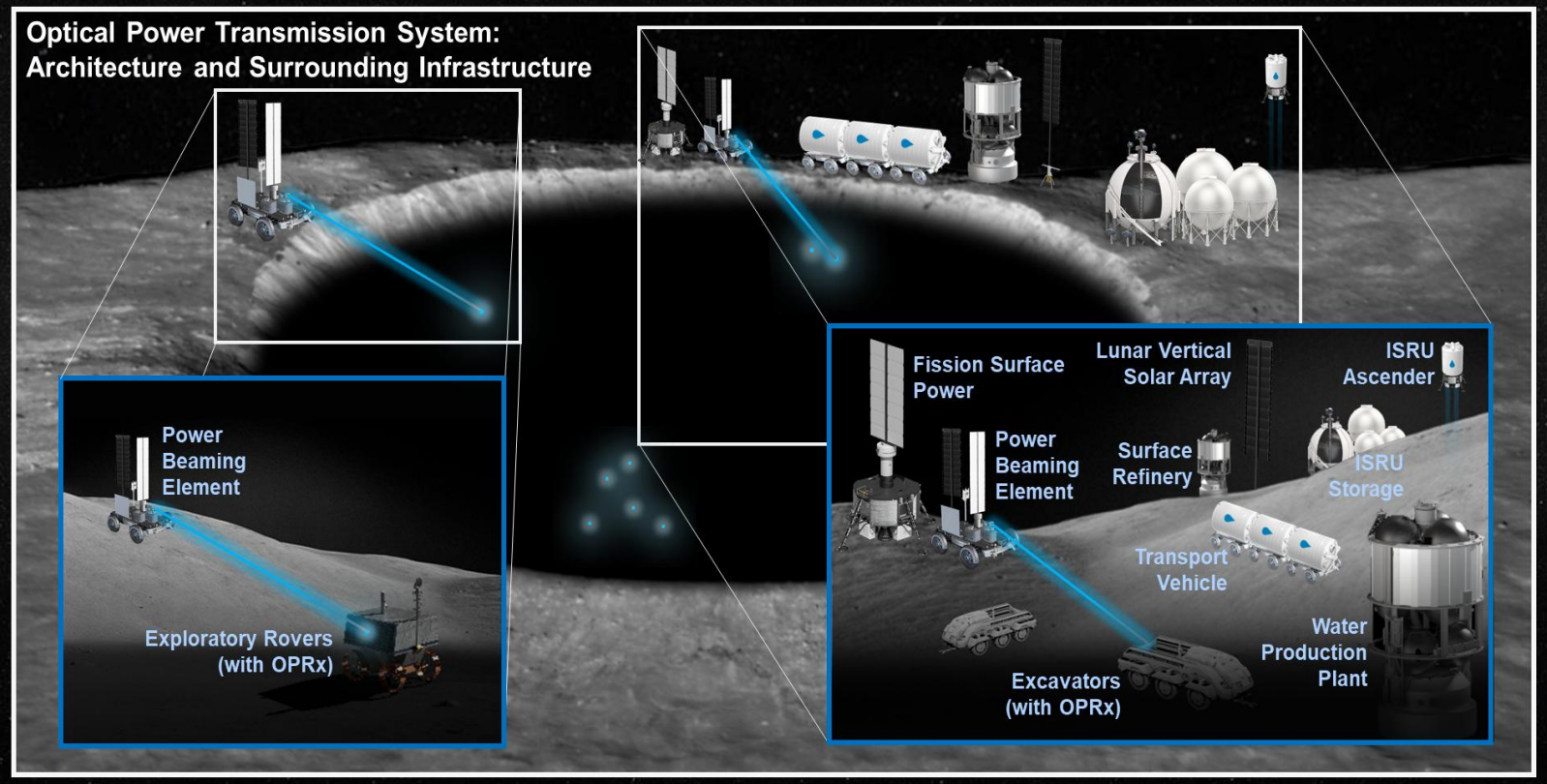
SUMMARY

- The lunar surface power architecture will serve as the fundamental backbone of future lunar infrastructure development



- Optimize the architecture for effectivity, efficiency, and resilience
- OSA design principles can be leveraged to implement a sustainable architecture that persists indefinitely

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