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Introduction: The Artemis era is here. Artemis I has successfully launched with NASA's Space Launch System (SLS) and Orion, circling the Moon and safely returning to Earth. This is the first of multiple missions to the Moon, which will require infrastructure for sustained lunar exploration [1]. The critical component of lunar infrastructure is power. Power on the Moon is required for robotic and human exploration, at a local, regional, and global level. Without lunar power readily available, lunar missions are constrained to the power they bring with them in the form of batteries and solar arrays. Surviving the lunar night, mobility, science, and habitation all benefit from readily available power on the Moon.

This presentation will discuss a lunar power architecture concept developed by Lockheed Martin, addressing elements of power generation, energy storage, power loads, and power management and distribution (PMAD). The goal of this architecture is to develop concepts for lunar power infrastructure aligned with Artemis missions to support humanity's exploration of the Moon. Specifically, architecture concepts are being developed to inform Lockheed's technology development strategy and to help the community and NASA make decisions on the right architecture to deploy.

Lunar Power Architecture Design: A lunar power architecture includes a lunar surface power grid. The development of a grid is a complicated, incremental, and long-term endeavor.

By understanding the functions of the different elements of the decomposed architecture, key interfaces can be identified, defined, and ultimately standardized. The Lunar surface power grid can broadly be defined in the four following functional classes, comprising of elements:

Power Generation—Elements that produce power that is consumed by the grid (i.e., power source)

Energy Storage—Elements that store energy produced by the grid before it is consumed

Power Loads—Elements that consume power produced and stored by the grid

Power Management and Distribution (PMAD)—Infrastructure that connect all element endpoints, manage communication, execute load control, and implement fault protection

The functional classes and respective elements are in Figure 1. Specific technologies such as Vertical Solar Array Technology (VSAT), Fission Surface Power (FSP), and reduction-oxidation (redox) flow batteries will be discussed in more detail in the presentation.

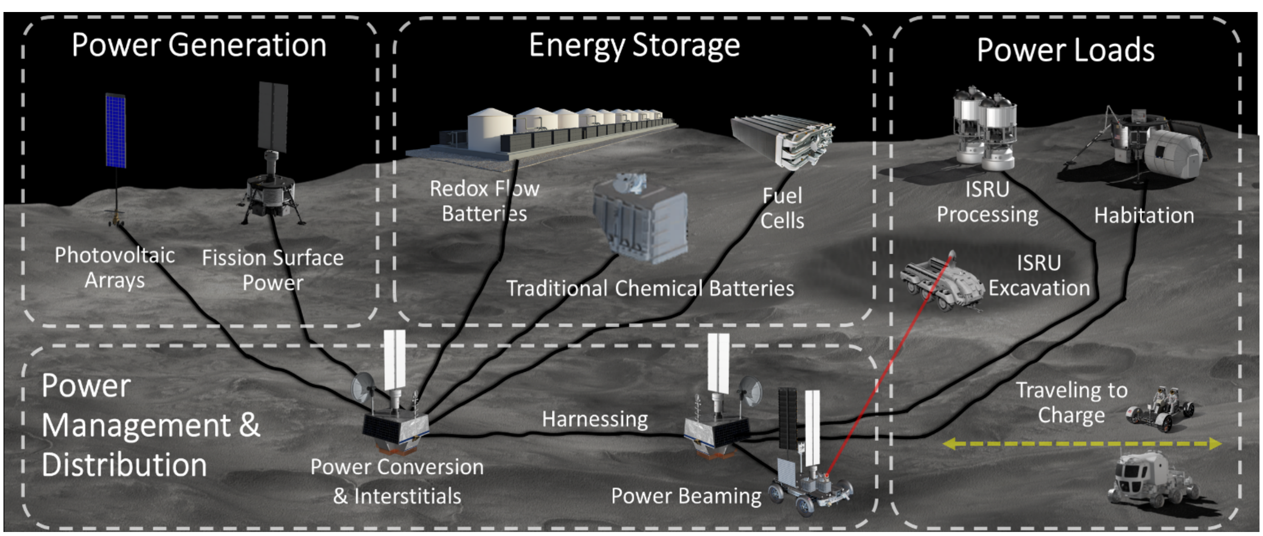

Figure 1. Power flows from left to right as it is produced, stored, and consumed

Lunar Surface Power Distribution Grid Key Characteristics: A sustainable lunar surface power grid architecture should be effective, efficient, and resilient [2]. *Effective* execution of a lunar grid requires that a) power generation and storage elements are able to meet the steady-state and dynamic power load demands, b) that power is successfully delivered to the locations of these loads, and c) that the power loads are managed within the performance capability of the power grid. Lunar power grid implementation must also be *efficient*, maximizing the delivered value while minimizing grid infrastructure development costs, operational costs, scaling costs, both transmission and conversion power losses, and total grid mass. Lastly, the grid must be *resilient* in that it must mitigate cascade faults, persist through individual element faults or re-configurations, and demonstrate both system reliability and fault response consistent with the tolerance of power loads.

Additional key characteristics are scalability and interoperability. The power architecture needs to scale with Artemis missions and other exploration needs. Interoperability is crucial for various organizations, such as US and global government organizations, industry, and non-governmental organizations to successfully operate on the Moon over sustained periods [3]. A preliminary power distribution grid is shown in Figure 2.

Conclusion: The next two decades will see the emergence of a busy commercial Lunar surface ecosystem with many diverse actors. Power is the critical element for scalable and sustained lunar exploration, and stable power sources at scale are required for In Situ Resource Utilization at scale. This presentation will describe a recommended lunar power architecture design, architecture elements, and key power distribution characteristics. Power availability is a foundational enabler of Lunar activities, and its lack of supply on the Lunar surface is a major barrier to entry. A cohesive, evolvable, interoperable global Lunar power grid will lower this and other barriers of entry to Lunar exploration so that a greater diversity of commercial and international partners can participate in the emerging Lunar economy.

References:

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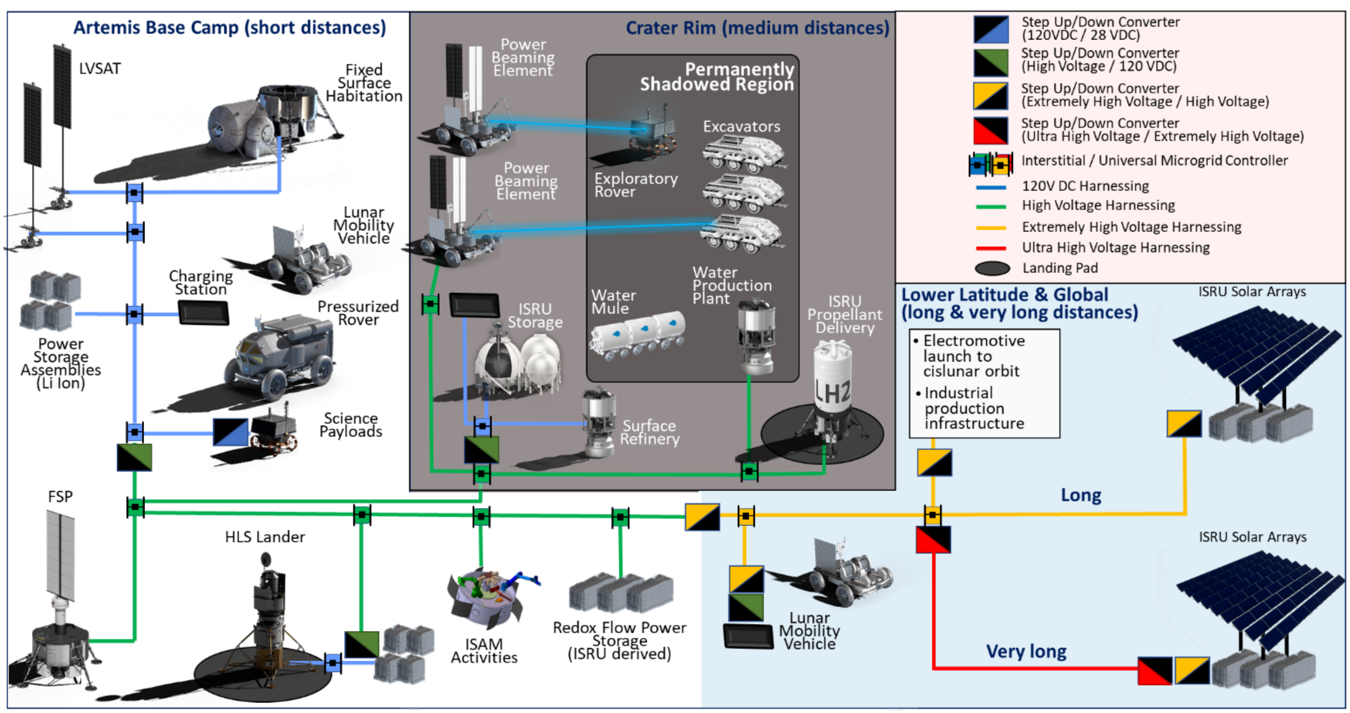

Figure 2. Preliminary lunar surface power distribution grid layout and evolution over greater distances.