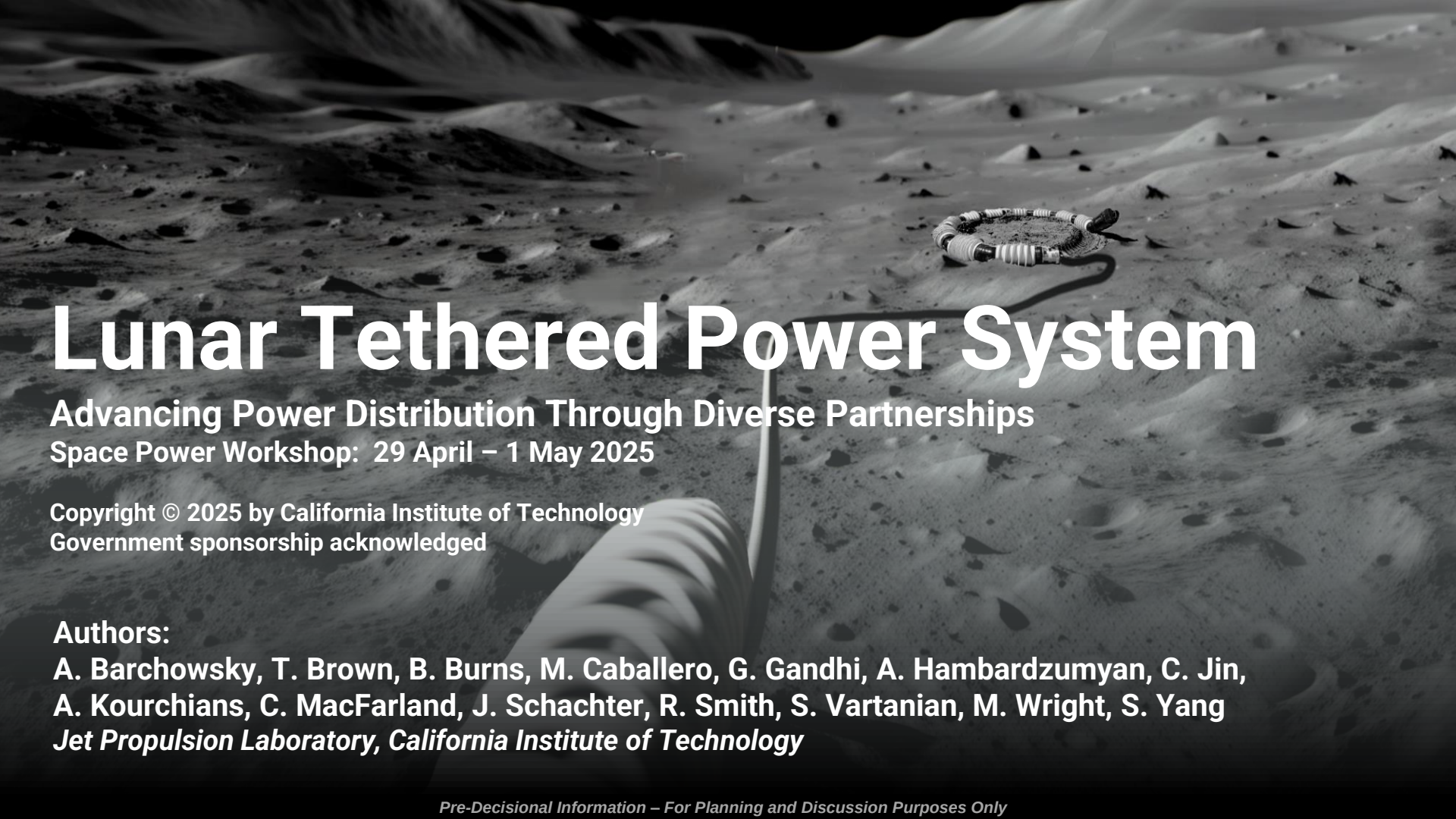

Lunar Tethered Power System

Advancing Power Distribution Through Diverse Partnerships

Space Power Workshop: 29 April – 1 May 2025

Authors:
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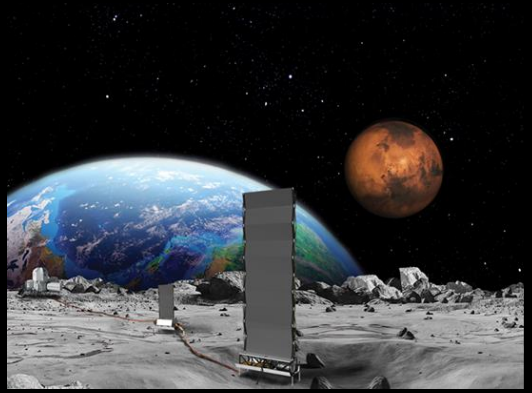
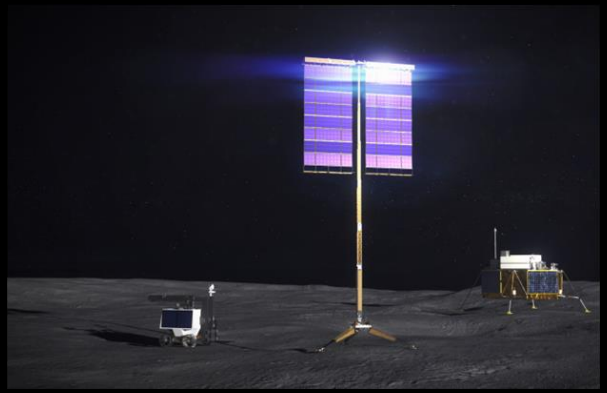
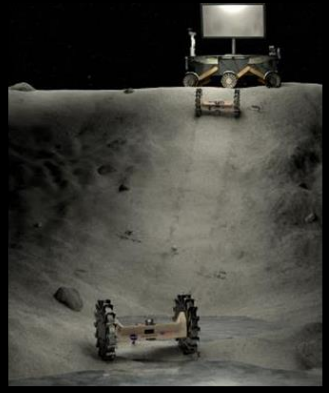
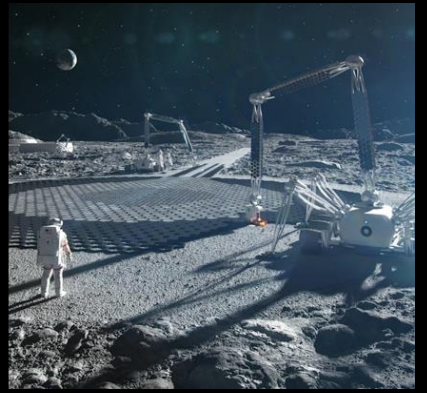
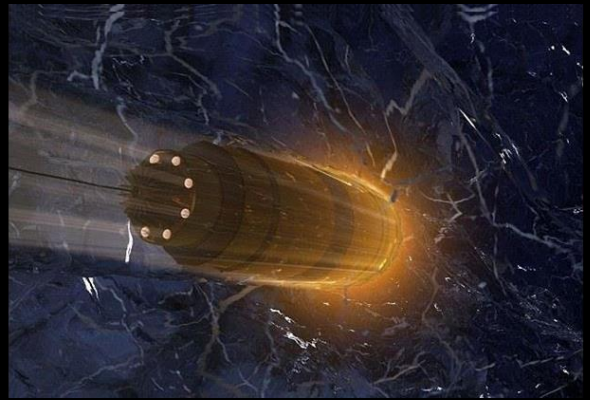
Jet Propulsion Laboratory, California Institute of Technology

Motivation

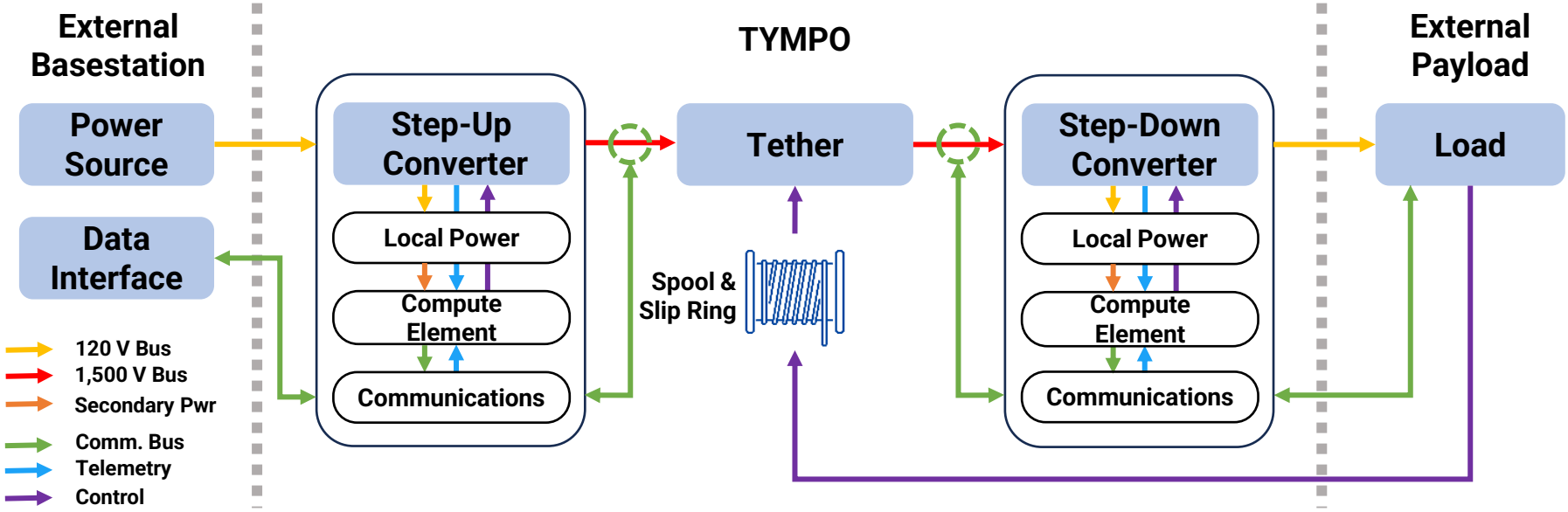
Connecting nuclear and solar power to remote payloads is essential for sustained Human and robotic presence on the Moon and Mars

Tethered high-speed communications, structural support, and abrasion resistance allow robotic platforms to explore new worlds

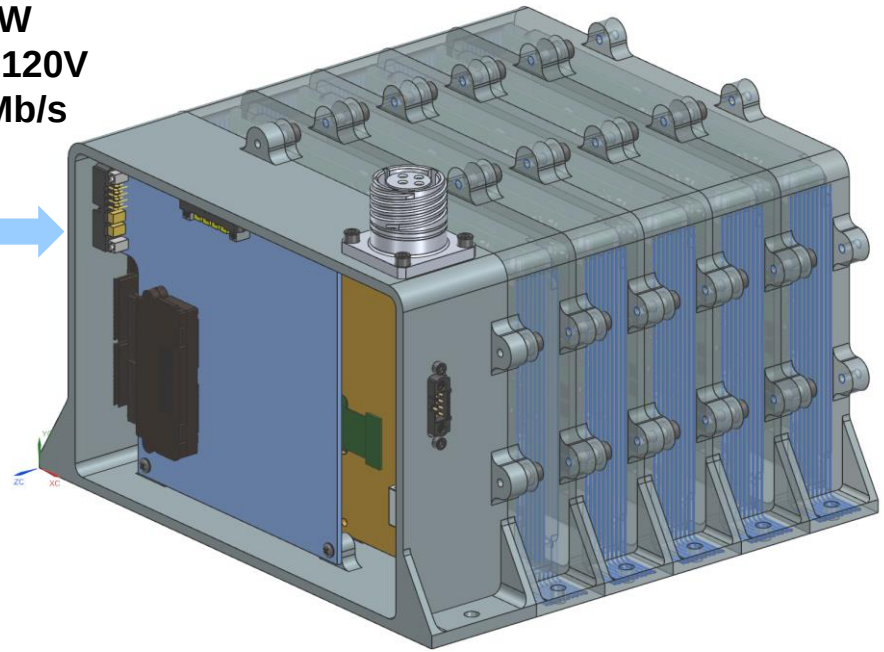
Project Overview

TYMPO is an end-to-end tether and electronics system, which could provide tethered robotics missions with power, communications, and tensile support. TYMPO is fully modular, allowing potential mission designers to scale the power conversion, communications link, and tether to their needs.

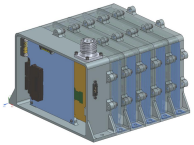


Interface Definition

1.5 kW
12.5A @120V
> 200 Mb/s



> 1 kW
> 8.3 A @ 120V
> 200 Mb/s



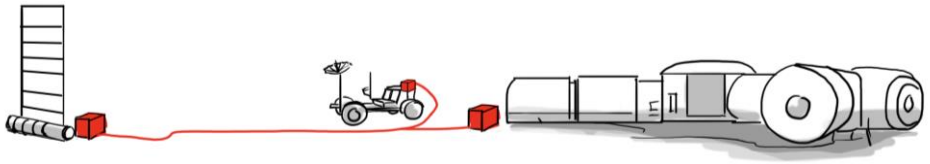
> 1km separation
bi-directional

1 Compute Element and 5 Power Converters

Applications

High-efficiency power transmission for surface nuclear or solar array power generation

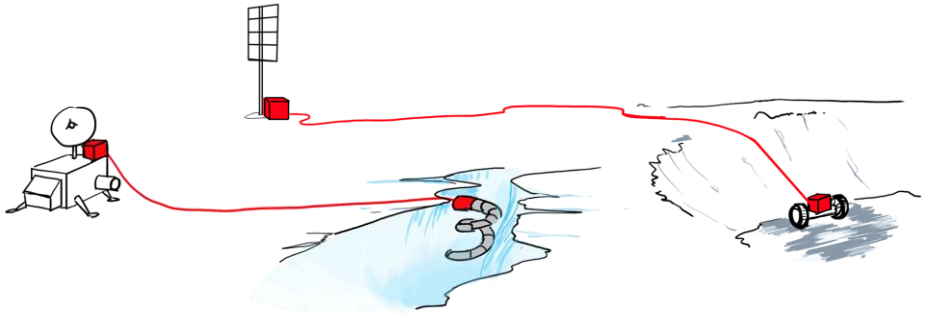
Tethered grids can provide power and communications between Artemis surface assets, supporting astronauts and their robotic systems



Robotic science and ISRU access to extreme terrain, like lunar craters, pits, and caves

Tethers with tensile support enable robots to explore Lunar permanently shadowed regions, investigating icy volatiles or resource utilization

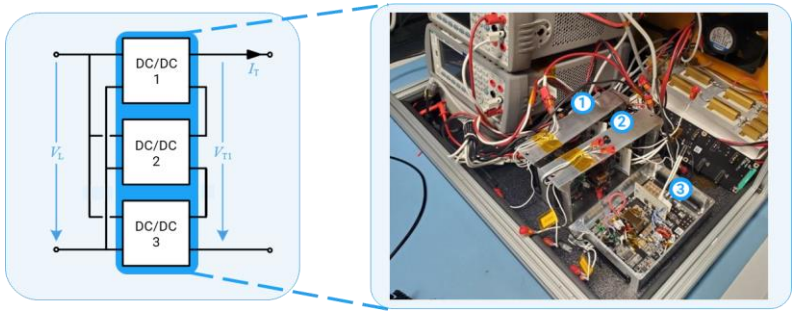
Tethered robots can explore extreme terrain and sub-surface features, utilizing power and communications without line of sight

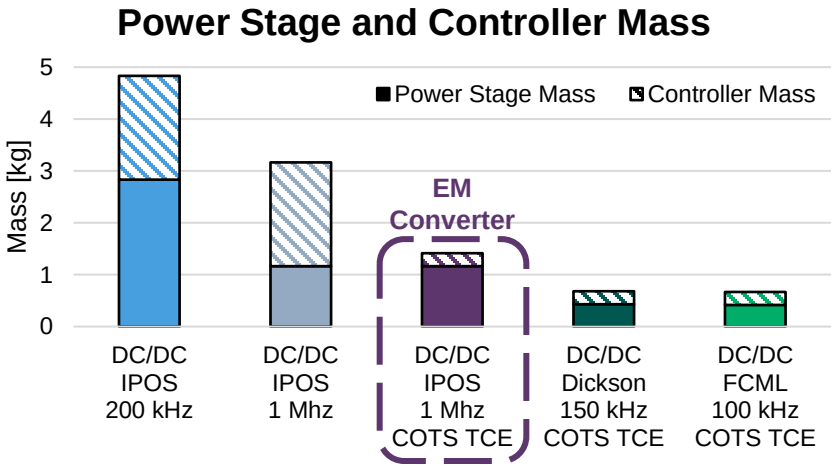


Modular Power Conversion

Power Delivery

- **Tethered power transfer** enables robotic mobility, science, and ISRU
- **DC power systems** provide the highest specific power at **greater than 2 kW/kg**
- **LLC converters** provide 1-10 kW at efficiency greater than 97.5 % in **modular 300 W blocks**

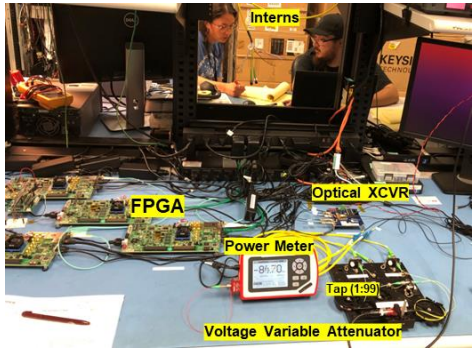




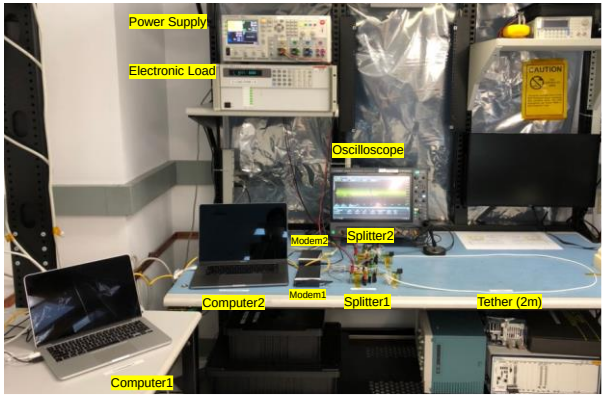
Dual Communications System

Communications

- **Tethered high-speed communications** allow large data transfer without line of sight
- **Singlemode fiber** optical communications provide above **1 Gb/s at up to 40 km**
- Surveyed industry to select **Commercial Fiber Optic Transceiver**
- **Power line carrier** communications use existing conductors to provide **10 Mb/s at up to 1 km**



Fiber Optic Comm Testbed

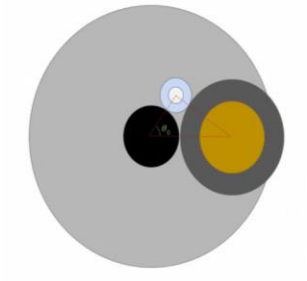


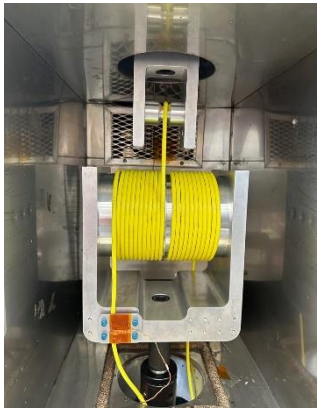
Power Line Comm Testbed

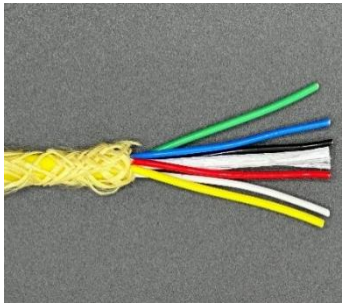
Configurable Lunar Tethers

Transmission

- **Tethers access** extreme terrain (pits, craters, PSRs) to enable unique surface missions
- **Tether scaling tools** have been published
- **Environmental testing** has proven Lunar PSR **tensile, abrasion, and therma**l capabilities





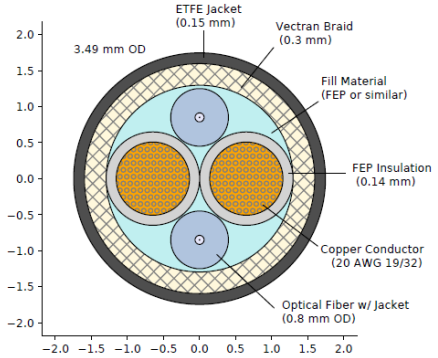


TetherCAD Tool

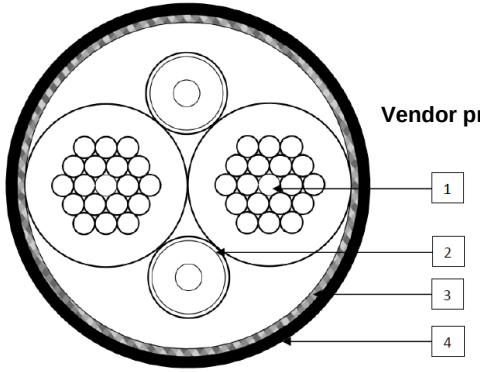
We've **built a tool that allows us to define optimized tether solutions for a given power level, voltage level, and distance**, using only existing components from wire and tether vendors. It is available here: https://github.com/nasa-jpl/TetherCAD and supports.

- Length
- Voltage
- Losses
- Power
- Tensile Strength
- Outer diameter constraint
- Inner constraint

Using TetherCAD, we have developed our EM Lunar cable and we are in the process of procuring it from one of several vendors.

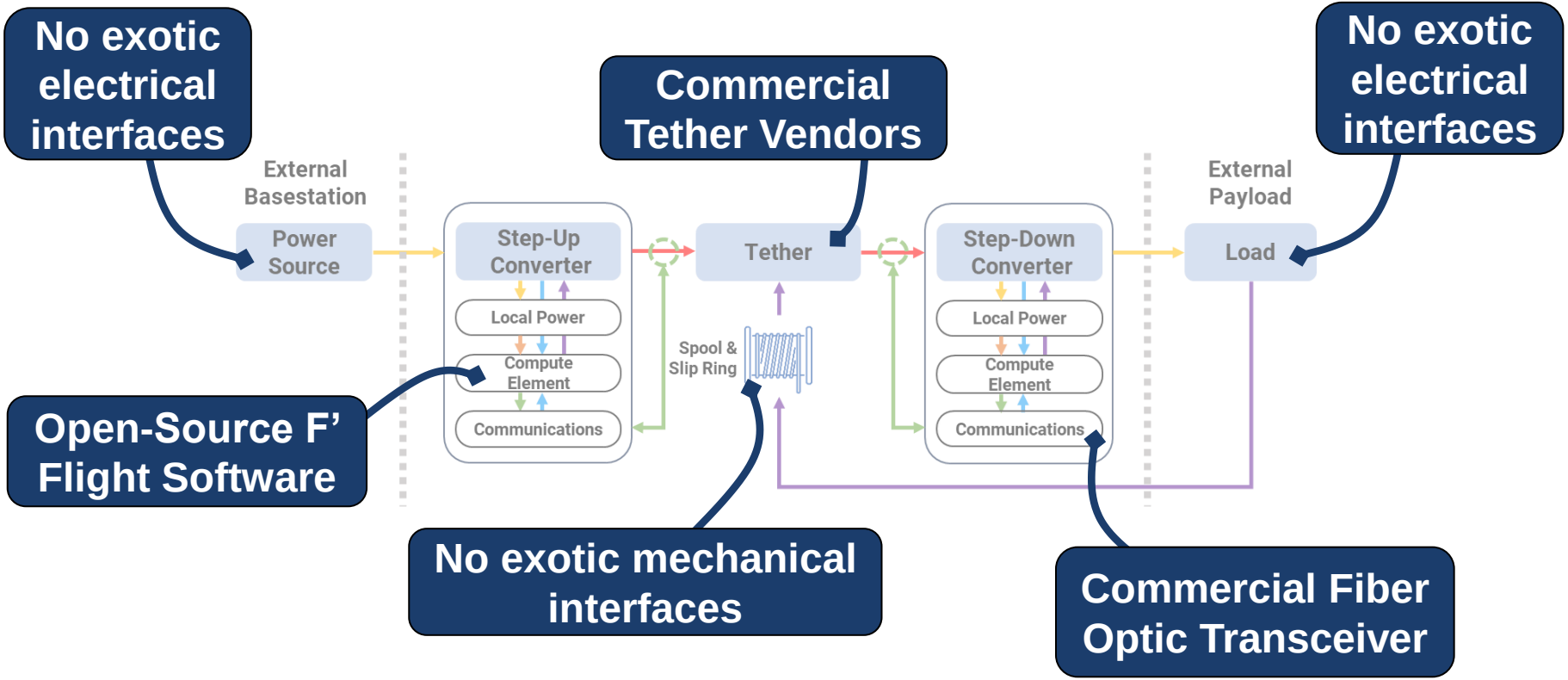


TetherCAD generated cross section for Lunar 1kW cable



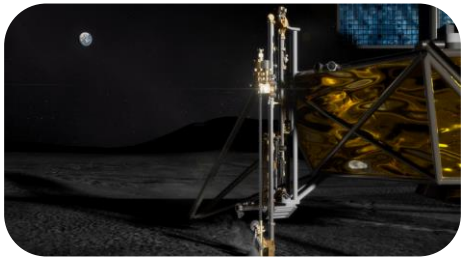
Vendor proposed solution

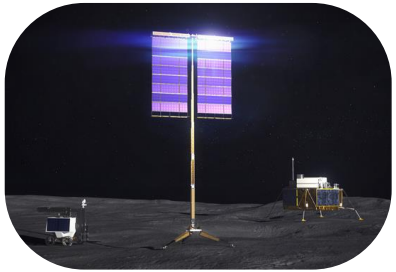
Commercial Infusion



Opportunities for Future Partnerships

- Permanently Shadowed Region Exploration
- Extend range of Human Landing System
- Lunar Power Grid Infrastructure
- Vertical Solar Array Technology
- In-situ Resource Utilization
- Tether Management & Cable Deployers





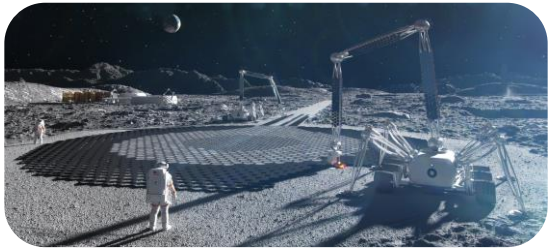
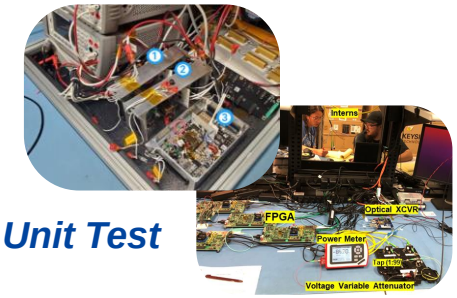


Photo Credit: NASA

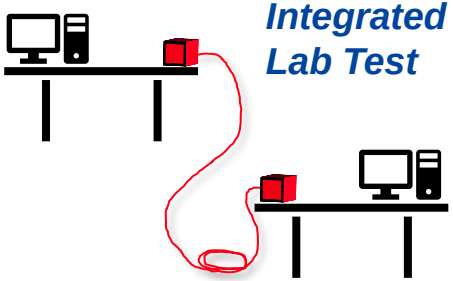
Unspooling the Future

Plans for 2025

- **Update & upgrade** electronics & tether design for power conversion & data transmission
- **Build** end to end system for greater than 1 kW & 1 km
- **Integrate & package** full system in flight like assembly
- **Flight scale demonstrate** of power and data transmission



Unit Test



Integrated Lab Test

Flight-Scale Demonstration