# LUNAR SURFACE WIRELESS POWER AND ANCILLARY SERVICES

Gary P. Barnhard[1] and Brad R. Blair[2],
[1]XISP-Inc, 8012 MacArthur Blvd, Cabin John, MD 20818 gary.barnhard@xisp-inc.com,
[2]XISP-Inc, 8012 MacArthur Blvd, Cabin John, MD 20818 brad@orbchem.space.

**Introduction:**

The ability to provide power and ancillary services (e.g., communications – command / control / telemetry / payload, time, navigation – range, rate, position, attitude) when and where needed is essential to virtually all aspects of human endeavor. It enables all forms of space exploration/development/settlement.

Defining an incremental path to realize the necessary power infrastructure to support settlement and its precursor activities is a significant systems engineering challenge.

More specifically, it is necessary to determine what are the increments of scalable, interoperable modular power and ancillary services needed to support exploration, prospecting, proving reserves, exploitation, habitation, and settlement of the lunar surface as well as how the requirements for the same can be accommodated. In addition, each power and ancillary services increment can provide the necessary power and services needed to construct the next increment.

A key aspect of managing the cost, schedule, and technical risk associated with Cislunar surface development is the timely development and availability of Lunar utility technologies and integration & interface standards, including the definition of Robotic Accommodation Requirements and Robotic Interface Standards. More specifically, a critical subset of interface standards for power, data, voice and video communications, navigation, time, thermal management, water, atmospherics, waste management, and control need to be defined in terms of their functional accommodation requirements; satisfactory and sufficient design elements; and prototyped, tested, and specific interface standards codified as appropriate: in short, what we refer to as Lunar Utility Technologies, Integration & Interface Standards.

The current state-of-the-art with respect to surviving and operating through the night on the lunar surface is profoundly limited. While there are multiple terrestrial and even space-qualified technologies that could be leveraged to design viable end-to-end power generation, storage, and distribution systems suitable for the lunar environment, the systems engineering of the same is nascent.

This paper will curate/generate, intersect, and converge multiple technology development efforts to yield recommended set of deployable power and ancillary services beaming infrastructure payloads.

- The first data set is the Vendor User's Guides for the NASA Commercial Lunar Payload Services (CLPS) contract lunar lander spacecraft and the data on the anticipated Human Landers.
- The second data set is the customer requirements of prospective payloads, which are broken into four increments. The first scalable modular increment of power services for initial exploration can be defined as up to 1 kW, a second more expansive increment to 10 kW supporting prospecting, a third increment to 100 kW proving reserves, and a fourth increment to 1,000 kW supporting exploitation, habitation, and settlement.
- The third data set is the accumulated theoretical/experimental test data on transmitter options, the rectenna/receiver options, and the end-to-end efficiency for microwave, millimeter-wave, and infrared/optical frequencies.

Working from the potential available input power increments, a similar scaling can be deduced. The DC-to-Beam conversion efficiency factored in, yielding estimates for the maximum power output electrical and the maximum power output thermal. Using the collection efficiency method, the received power can be calculated for various distances of interest. The resulting values will be translated into power and ancillary services infrastructure designs that are both robotic and EVA compatible for peer review. This paper will build on work last presented at IAC 2021 Dubai.

**References:**

[1] Barnhard, Gary P., Faber, Daniel, Space-to-Space Power Beaming - An Evolving Commercial Mission to Unbundle Space Power Systems to Foster Space Applications International Astronautical Congress, Guadalajara. Mexico 2016

[2] Barnhard, Gary P., Potter, Seth D., Challenges of Space Power and Ancillary Services Beaming: Key to Opening the Cislunar Marketplace, International Astronautical Congress Washington, DC 2019 Virginia, USA.

[3] Kazemi, Hooman (Raytheon), Millimeter wave Wireless Power Transmission Technologies and Applications, Space Solar Power Symposium, National Space Society ISDC 2019

[4] Barnhard, Gary P.; Potter, Seth D. “Power and Ancillary Services Infrastructure” poster and presentation for Lunar Surface Innovation Consortium (LSIC) Power Beaming Workshop, July 22-23, 2021

[5] Barnhard, Gary P.; Douglas, Seth D., “Bootstrapping Lunar Exploration To Settlement: Power And Ancillary Ser-vices Beaming”, IAC-21,C3,2,2,x67037 72nd International Astronautical Congress 2021 Dubai, paper and presentation October 26, 2021.

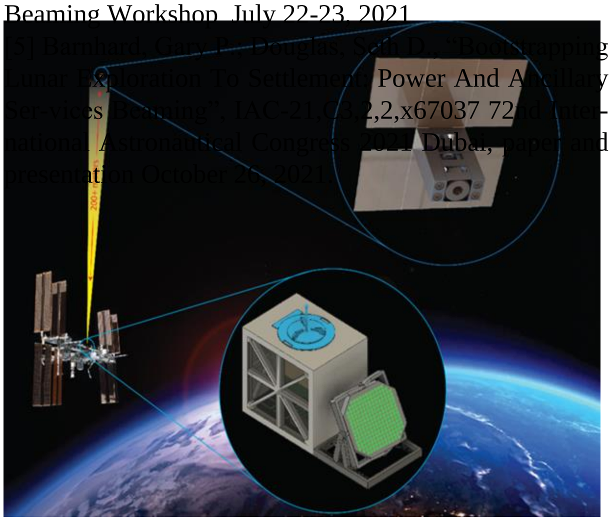

Figure 1 – XISP-Inc Space-to-Space Power Beaming ISS Technology Development, Demonstration, and Deployment mission proposed testbed.

Figure 2. – Sandia Labs has partnered with Raytheon and the Air Force Research Laboratory (AFRL) on Nonlethal weaponry — Sandia researchers Willy Morse and James Pacheco fine-tune the small-sized Active Denial System. (Photo by Randy Montoya).

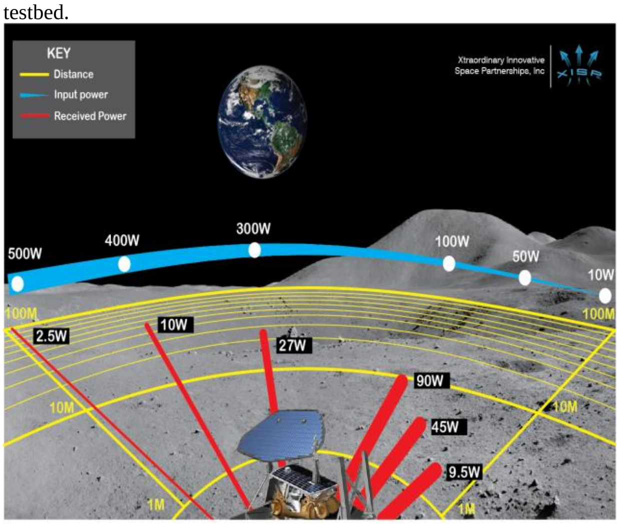


Figure 3 – XISP-Inc & Raytheon Proposal to repackage and integrate existing hardware into a lunar surface demonstration testbed that could provide power and ancillary services.

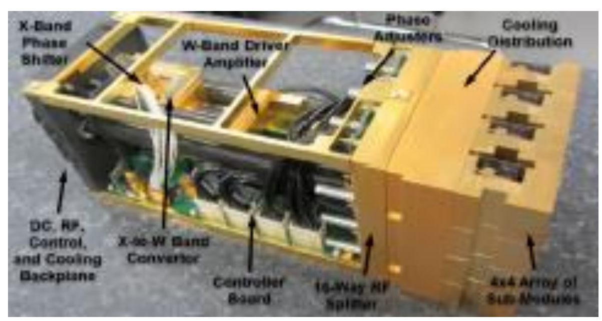


Figure 4 – Raytheon 100 W Module (4x4 Submodules).