Surface-to-Surface Customers: Meeting Customer Requirements

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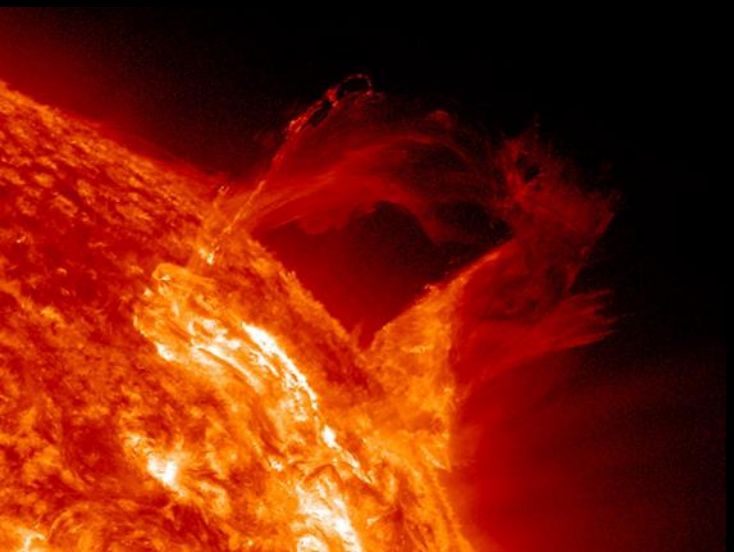
Surface-to-Surface Power Beaming & Ancillary Services

(1) The Opportunity
(2) Visualization
(3) Engineering for Success
(4) Building the Customer Base



Space Solar Power Key Considerations

- Space Solar Power is an applied engineering problem and an economics problem.
- Applications have significant systems engineering and economic challenges in each venue that must be successfully addressed.
- Each venue has different fundamental figures of merit which define their value proposition.
- Operational capabilities are best realized by leveraging a combination of technology development "Push" and mission requirements "Pull".
- Each increment of public and/or private investment should lead to an operational capability.
- Work Vectors: Technology Development → Demonstration → Deployment and Space-to-Space → Surface-to-Surface → Space-to-Alt Surface → Space-to-Earth

Key Variables

- Cost/Economics (initial cost to first power, LCOE, market viability, anchor customers),
- Frequency/Wavelength (microwave to eye safe optical),
- Distance (near field, boundary regions, far field),
- Magnitude (i.e. power level supporting application)
- Duration (pulsed, scheduled, continuous),
- Availability (on demand, scheduled, prioritized, by exception),
- Security (misuse, interruption, destruction), and
- Performance (net transfer, end -to-end efficiency, piecewise efficiency, steering precision and accuracy, beam shaping, effective operational difference).
- Duty cycle of services (baseload power, peak power, augmentation of power during lunar night or in shadowed regions, storage and buffering of data for later transmission, etc.)
- Altitude of Transceiver versus terrain features (lander height, telescoping deployment mechanism, terrain features height)

Technology Development, Demonstration, and Deployment (TD^3) Mission Context

Space Power & Ancillary Services Beaming TD^3 mission context

Technology Development

- **Flight qualified SSP&asB transceiver**
- **Flight qualified SSP&asB reflectarray rectenna/solar array/Tx&Rx antenna**
- **Deployable Power Generation & Relay Towers**
  - **solar concentrator/reflector**
  - **reflectarray rectenna/solar array/Tx&Rx antenna**
  - **telescoping tower**
  - **deployable apertures**
- **Foster Clients/Customers**
  - **Powered Rover**
  - **Powered Prospector**
  - **Powered Miner**
  - **Volatile/Metal Separation**

Technology Demonstration

- SSP&asB
  - Survive the Night
  - Augment for power tools & instruments
  - Battery recharge
  - Evolving Power & Ancillary Services Utility

  ➔ Emergency

  ➔ Servicing

  ➔ Augment

  ➔ Backup

  ➔ Primary
- Foster Clients/Customers
  - Volatiles Mining Demo
  - Propellant Depot Demo
  - Metals Mining Demo

Technology Deployment

- Dispatchable Power & Ancillary Services
- 24x7 Operations Support
- Watt to Kilowatt Scale Service
- Precursor to Kilowatt to Megawatt Scale Services for Lunar facilities

Space Solar Power Problem Space

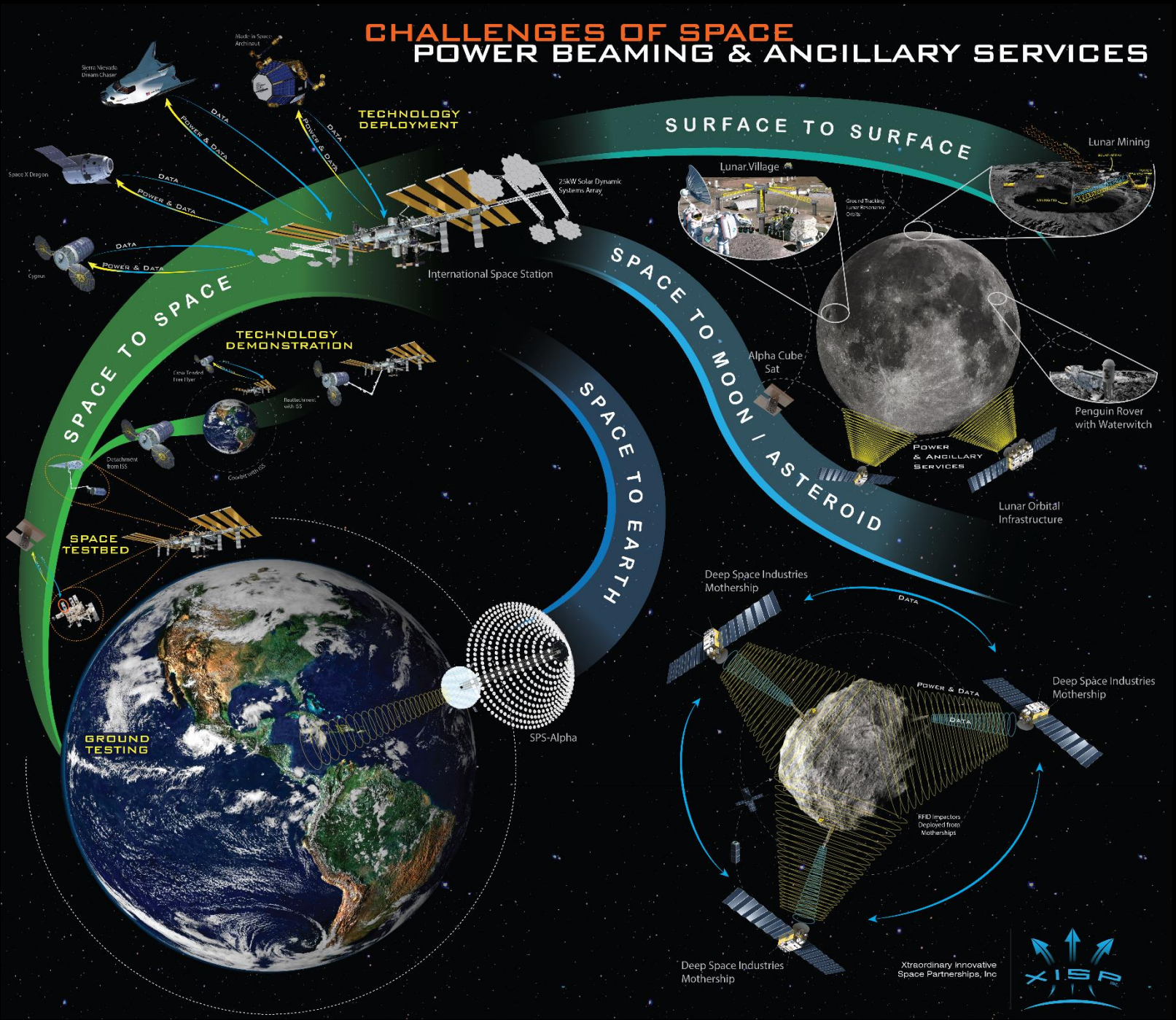
Technology Development

Venues	Ground	Space
Space - to - Space	• Cognitive SDR Transceiver • Converged Electro/Optics • W Band & Optical Apertures • Piecewise Efficiency • Reflectarray Rectenna • Beam Forming • Management Operations Control Applications (MOCA)	• ISS Mounted Transceiver • Deployable Rectenna • 6U Flight Test Article • Optimized Frequencies • End-to-End Efficiency • Scaling/Modularity (Gen, Trans, and Control) • Multiplexing Services • MOCA S/W & Data System
Surface - to - Surface	• Deployable Power Generation & Relay Towers • Conformal Rectenna • Deployable Rectenna • Solar Concentrator/Reflector	• Powered Rover • Powered Prospector • Powered Miner • Volatile/Metal Separation
Space - to - Moon / Asteroid	• Disaggregatable Flight Systems Technology • Scalable Transceiver • Scalable/Printable Rectenna • Management Operations Control Applications (MOCA)	• Mothership with deployable sensors/rovers • Distributable Rectenna • Lunar Resonant Orbits • Beam Steering (Phased Array & Gimbals)
Space - to - Earth	• Lunar Resource Model • Asteroidal Resource Model • Drive launch costs down to $100/kg to LEO • Atmospheric Transparency • Beam Management -- Frequency/Control/Security • MOCA Authentication, Authorization and Control System	• Modular Structure I/Fs (mechanical/robotic/ control/thermal) • Thermal Management • Pointing Large Structures • Electro-Magnetic/Optical Alignment • Solar Dynamic Modules • Non-Iridium Based Concentrated Photovoltaic

Space Solar Power Solution Space

Operational Capability/Applications

Venues	Technology Demonstration	Technology Deployment
Space - to - Space	• ISS Co-orbiting Crew Tended Free Flyer Demo • Propulsion Augment Demo • Space Based Propellant Depot Operations Demo • Disaggregated Formation Flying Spacecraft Demo • Plug in/Plug Out Tech Demo	• Power & Ancillary Services Beaming Interface Kit(s) • Dispatchable Power & Ancillary Services • Cislunar Propulsion Services • Kilowatt scale services
Surface - to - Surface	• Power & Ancillary Services Beaming - Survive the Night • Volatiles Mining Demo • Propellant Depot Demo • Metals Mining Demo	• Dispatchable Power & Ancillary Services • 24x7 Operations Support • Kilowatt to Megawatt Scale Services
Space - to - Moon / Asteroid	• Power & Ancillary Services Beaming Demo • Lunar Assay & Mining Demo • Asteroidal Assay & Water/ Volatiles Mining Demo • Asteroidal Optical Drilling, Volatiles Mining & Demo • Metal Refining Demo • Planetary Defense	• Synergistic impact of Cislunar Development • Dispatchable Power & Ancillary Services • 24x7 Operations Support • Megawatt to Gigawatt Scale Services
Space - to - Earth	• Power & Ancillary Services Beaming to UAVs & Others • Power & Ancillary Services Beaming to Forward Bases • Power & Ancillary Services Beaming to Terrestrial Grid	• Synergistic impact of Cislunar Development • Dispatchable Power & Ancillary Services • National and International Geopolitical High Ground • Gigawatt to Terawatt Scale Services

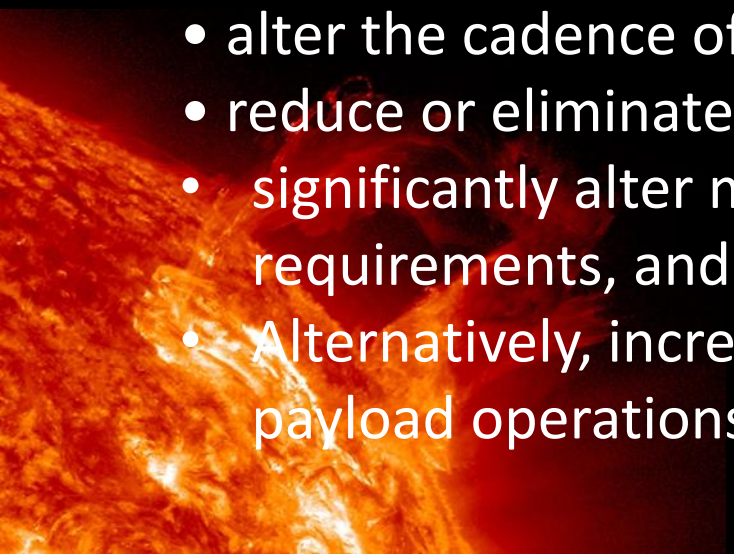

CHALLENGES OF SPACE
POWER BEAMING & ANCILLARY SERVICES
TECHNOLOGY DEPLOYMENT
SURFACE TO SURFACE
SPACE TO SPACE
SPACE TO MOON / ASTEROID
SPACE TO EARTH
TECHNOLOGY DEMONSTRATION
SPACE TESTBED
GROUND TESTING
International Space Station
25kW Solar Dynamic Systems Array
Lunar Village
Lunar Mining
Alpha Cube Sat
Penguin Rover with Waterwitch
Power & Ancillary Services
Lunar Orbital Infrastructure
SPS-Alpha
Deep Space Industries Mothership
Deep Space Industries Mothership
Deep Space Industries Mothership
RFID Impactors Deployed from Motherships
Xtraordinary Innovative Space Partnerships, Inc
DATA
POWER & DATA

Surface-to-Surface Power & ancillary services Beaming (SSP&asB)

Technology Development, Demonstration, and Deployment (TD^3) Mission

XISP-Inc has hypothesized that unbundling/disaggregating power systems (i.e. the separation of power generation, transmission, control, storage, and loads) and alternate provisioning of ancillary services can:

- reduce spacecraft and/or instrument complexity, mass and/or volume
- allow reallocation of mass and/or volume
- alter the cadence of mission operations
- reduce or eliminate solar pointing requirements
- significantly alter mission lifetime, reduce power requirements, and increase return data rates
- Alternatively, increase available power when needed for payload operations or charging to survive the lunar night.



Lunar Surface Instrument and Technology Payloads (LSITP) Opportunity

This payload will demonstrate the ability of Surface-to-Surface Power & ancillary services Beaming (SSP&asB) technology to be used to provide wireless utility services (e.g., power, data, communications, navigation, time, heat, etc.) to multiple Clients/Customers (C/C) in the lunar environment in a cost and resource effective manner.

XISP-Inc SSP&asB LSITP

- This payload is part of a Technology Development, Demonstration, and Deployment (TD^3) mission which has the following specific objectives:
  - Technology Development: leverage existing hardware from other missions/applications that can be repackaged as a lunar payload to serve as test bed equipment that supports the characterization, optimization, and operational rule definition for uni-directional, bi-directional, and relay SSP&asB. Since this is a new application of existing equipment the Technology Readiness Level (TRL) is by definition reset 5. This mission will advance the TRL to 9 for SSP&asB.
  - Technology Demonstration: The SSP&asB test bed equipment will then be used to demonstrate the ability to support other payloads power and ancillary services requirements.
  - Technology Deployment: The SSP&asB test bed equipment will be made available as configurable/evolvable infrastructure for subsequent missions/applications.

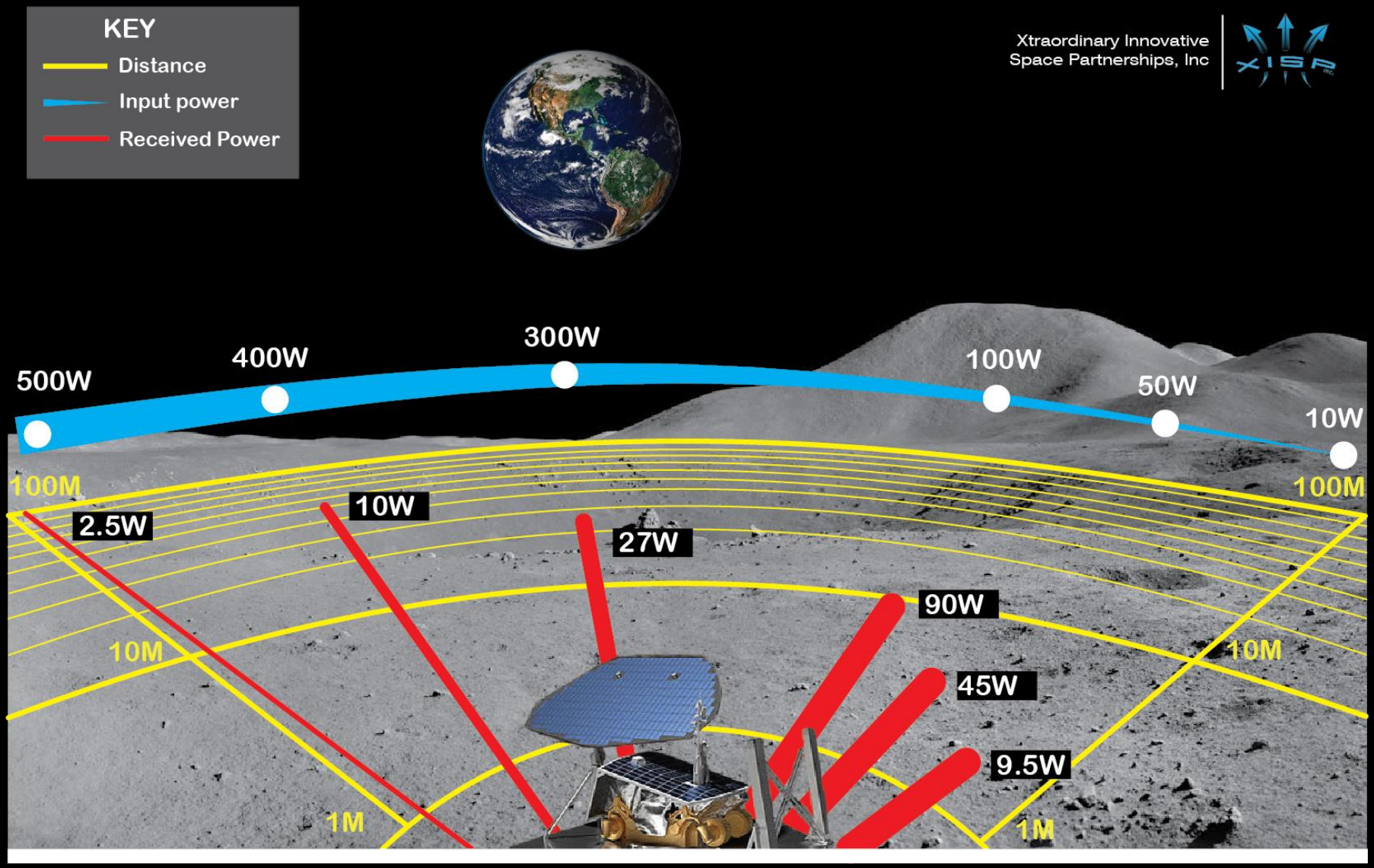
SSP&asB Perceived Impact of Work

- The availability of power and ancillary services (e.g., communications, data, navigation, time, etc.) is essential to most if not all aspects of lunar operations.
- The unbundling of space electrical power systems (i.e., separation of power generation, transmission, distribution, control, and loads) affords opportunities for redistribution of mass, overall volume, surface area, and complexity which can be mission enhancing/enabling.
- Increasing the availability of power and data transfer performance while simultaneously reducing the resource burden (mass, power, volume) to achieve the same that must be borne by the Clients/Customers will be mission enhancing if not mission enabling.

SSP&asB Relevance to the Solicitation

- *This work is directly relevant to Power Generation, Distribution, and Energy Storage, and supports all the other stated areas of interest for technology demonstrations.*
- More specifically, it impacts power generation, distribution, and energy storage by allowing for the reallocation of mass, power, and volume between the supporting infrastructure and the payload. Allowing more payload experimental data to be collected and returned for analysis.
- A visualization of the beaming field relating distance from the lunar lander to the Client/Customer, transmitted power, and received power is shown in Figure 1 – SSP&asB Mission Visualization.

Surface-to-Surface Power & Ancillary Service Beaming



SSP&asB Technical Approach & Methodology

- The integrated payload will consist of a frequency selectable power transmitter (92 GHz is the baseline) and a frequency agnostic (Ka Band is the baseline) cognitive Software Defined RF transceiver with a gimballed low profile transmitter/transceiver array, related control electronics/software with compliant interfaces, as well as the interface specifications/rectifying antenna (rectenna) kits for Customer/Client use.
- The flight configuration will be determined by a technical bake off test. Based on the results of the test XISP-Inc will relocate the interface planes allocating functions to corresponding vendors.

Lunar Power & Light Company

Conclusion

- Step-1 NASA Science Mission Directorate Solicitation Proposal was accepted
- Step-2 Proposal under evaluation
- There is now a defined confluence of interests biased toward successful execution of the mission as public private partnership.
- Commercial space applications include:

1. enabling expansion of operational mission capabilities,
2. enhanced spacecraft/infrastructure design flexibility, and
3. pave the way for the Lunar Power & Light Company.

Don't wait for the future, help us build it!

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