A Deep Space Multi-hop Power Grid Infrastructure Using Space Solar Power Satellites. Corey Bergsrud[1] and Jeremy Straub [2], [1]Department of Electrical Engineering, Upson Hall II Room 160, 243 Centennial Drive Stop 7165, Grand Forks, ND, 58202-7165, corey.bergsrud@my.und.edu, [2]Department of Computer Science, 3950 Campus Road Stop 9015, Grand Forks, ND, 58202-9015, jeremy.straub@my.und.edu.

Introduction: The concept of Space Solar Power Satellites (SSPSs) as an enabler for Mars and Lunar scientific, industrial (mining, processing, manufacturing), and launch activities via supplying electrical power via microwave energy has been presented in [1, 2]. In [1], the need to implement an Earth-Moon transportation system to transport resources and materials from the Moon to the Earth or from Earth to the Moon was presented. This Earth-Moon transportation system was designed to be powered by SSPSs.

A similar analogy was used in [2]; however, the point of an Earth-Mars chain of SSPSs was to transmit energy via a multi-hop network of power storing and forwarding spacecraft. This would start with SSPSs that were close to the Sun and beam (using very high energy concentration and narrow beamwidths) to SSPSs that were further away from the sun until eventually the energy got to the Mars location and was distributed to support Martian activities. This same architecture could be utilized to support the power needs of spacecraft in-route from Earth to Mars.

This paper presents a prospective system which would utilize a collection of SSPS spacecraft to support a tortile-style orbit-based highway from the Earth to the Moon or the Earth to Mars. This would allow spacecraft to reduce their mass and volume via not carrying large solar panels (small panels would be needed as a contingency measure) and thus facilitate lower cost electric-propulsion-based travel.

An Astro-Highway System for Electrically Propelled Spacecraft: The Astro-Highway would consist of a collection of SSPS spacecraft in circular Earth (in the context of the Earth-Moon highway) or Solar (in the context of the Earth-Mars highway) orbits which would regularly align to allow a tortile-style traversal to be performed with the spacecraft passing close to the SSPS units during the transfer. During the periods in proximity to the SSPS units, the spacecraft's systems would operate off of the supplied power and internal batteries would be recharged to sustain the spacecraft during periods of traversal between SSPS coverage areas.

The number of SSPS units placed into each orbit would determine the frequency of these tortile traversal opportunities as well as the fraction of time that the spacecraft would spend in range. The number of spacecraft deployed also influences what the effective range is, with the SSPS units being potentially forced to power further away craft (with more free-space loss) in lower-number-of-spacecraft configurations.

Benefits of Grid / Astro-Highway System: The proposed Astro-Highway would allow spacecraft to utilize electric propulsion (EP) technologies. EP increases the value of each mass-unit of propellant via ejecting it at high velocity (and thus creating greater force). However, this value is offset by the mass required for the power generation and power management and distribution systems on the spacecraft. Generation, in particular, which requires large mass and volume solar arrays and the supporting truss mechanisms, offsets some of the benefit of this technology.

Using SSP, a smaller receiving (rectenna) area can be utilized to receive the much higher density microwave beam transmitted by the SSPS craft. This reduces the mass and volume needs on the spacecraft, allowing the propellant ejected to be more effective in generating velocity changes for the spacecraft.

Prospectively Linking The Two Networks: Some parts of the Lunar and Martian SSPS networks may be able to be shared between the two networks. For example, those that are in close proximity to the Earth would be ideal candidates for dual-use. The shared grid would be designed to power in future exploration craft journeying to the Moon and Mars. In addition, some of the spacecraft could potentially supply power to the surface of the Earth, the Moon and Mars when not needed for transportation use. A model for a multi-hop relay network was presented in [3], all be it for communications purposes.

Expansion of the Astro-Highway System: In the longer term, an expanded network could prospectively serve more distant planets. This would potentially enable future exploration of the outer solar system.

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