”Energy Orbit “ Wirelessly Powering Satellites using Small Space Solar Power Satellite Constellation

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論 文 名　：“Energy Orbit” Wirelessly Powering Satellites using Small Space Solar Power Satellite Constellation
（エネルギー軌道－宇宙太陽光発電衛星コンステレーションを用いた衛星への無線電力供給）

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論　文　内　容　の　要　旨

Wireless Power Transmission (WPT) technology using a satellite-to-satellite system represents a valuable and convenient technology for transferring power wirelessly among Space Solar Power Satellites (SSPS) to Satellite and potential upcoming interplanetary missions. This direct transmission offers a possible solution to deliver continuous, convenient, and unlimited energy supply to satellites help replace traditional power storage and reduce the weight and ultimately the costs of launching satellites. Satellite industries traditionally use photovoltaic cells and nuclear generators to satisfy the needed electricity needed by spacecraft. Current power generation and effective management systems occupy up to 10-25% of the satellite's mass.

The concept of laser-based WPT from Energy Satellite (E-Sat) can overcome substantial problems. The current design of SSPS primarily focuses on designing a massive satellite to generate and transmit gigawatts of energy to an Earth-based ground receiving antenna. This consistent idea can be adopted for spacecraft by developing a constellation of E-Sat called Energy Orbit (E-Orbit) to supply sufficient power to spacecraft within range. It will increase the impressive performance and operational lifetime, especially for small and cube satellites using microwaves and laser-based power transmission. By developing a small scale SSPS, E-Sat for WPT application in space, followed by a practical demonstration of mother-daughter satellite and accurately evaluating the possibility for subsequent implementation. In addition, Creating 1600 E-Sats constellations to fulfill the power demand in low earth orbit.

Nevertheless, another potential avenue where E-Orbit supports a possible application is its utility towards rovers and habitat. For instance, the rovers find it difficult to investigate in the far side, crater, and polar region of the Moon, where sunlight is unavailable for a few days. This challenge can be suitably overcome by employing an E-Sats, which can be used for WPT, independent of its location. Such techniques demonstrate possible applications towards power transmission for unmanned aerial vehicles for faster mapping purposes. As such, the dependence of those aerial vehicles towards fixed energy storage becomes alleviated. Simultaneously the future habitat on Mars and the Moon will receive continuous power by developing a perfect Mars and Moon E-Orbit system for interplanetary and solar-system investigation mission satellites to achieve continuous power.

The theoretical modeling allows the analysis of power conversion or transmission for each unit in terms of laser impacts, transmission efficiency, and photovoltaic-cell thermal property. Maximum power transmission efficiency is calculated based on a linear approximation of power conversation between electricity-to-laser and laser-to-electricity validated by numerical simulation. This efficiency variation depends on the selection of Laser, transmitter, transmission distance, and photovoltaic cells, the same as increasing the maximum transmission efficiency of information in a wireless communication network. Consequently, this thesis gives insight into wireless power transmission in general and adequate guidelines of the satellite to satellite power

transmission system design in practice. The development and demonstration of this technology can help fulfill Space Solar Power Satellites' idea to transfer gigawatts of renewable energy to Earth.

Chapter 1: Introduction: This chapter contains the literature review for the energy crisis on Earth concerning the ever-growing population. The production of affordable electricity from renewable and nonrenewable energy and associate problem. Implement a new renewable power system and economic production using space-based SSPS and unique challenges to design it. The current power management systems for space and associated technologies efficiently utilize to sufficiently support diverse missions around Earth and interplanetary mission. Creating E-Sats and a constellation design in low Earth orbit E-Orbit.

Chapter 2: Literature Review and E-Orbit Refence Mission Designing: This Chapter includes the necessary information on and overviews of SSPS designing and the historical development of WPT, and remarkable experiments efficiently conducted from all over the world. The numerical analysis and exercise of microwave and laser systems for wireless power transmission. The current policies and key challenges around space solar power and wireless power transmission system designing. Discussed the reference parameters for E-Sat and E-Orbit.

Chapter 3: Energy Satellite: The system analysis and system engineering to develop a small-scale SSPS properly as E-Sat. The essential components, high accuracy attitude, orbital control subsystem, propulsion subsystem, active sensors, power generation, and management unit, including laser power transmission subsystem as payload for E-Sat. The power transmission efficiency and power density at receiving object to satisfy user requirements. The novelty of E-Sat compares to the historical SSPS design. The necessary orbital variables and their operational performance inside the proper orbit.

Chapter 4: Energy Orbit: The practical importance of Energy Orbit and the formation flying of E-Sats in low Earth orbit. Orbital characteristics to properly transfer continuous non-disruptive laser power to customer satellite and maintaining power across Energy Orbit. The orbital characteristics and continuous interaction with the customer satellite with the specific decided range of power transmission. The system modeling and necessary phase to phase timeline for progressively developing Energy Orbit across low Earth orbit. Numerical analysis and the other significant scenario can tackle the debris removal, laser propulsion, safety, deorbiting, orbital maneuver—the driven economy and potential revenue within the 20 years of launching Energy Orbit in space. In addition, this key section suggests and recommended few subsequent policies to properly consider for the successful development of SSPS and WPT in the context of E-Orbit.

Chapter 5: Interplanetary Energy Orbit: The designing and power support system for Moon and Mars as Moon Energy Orbit and Mars E-Orbit, respectively. The Constellation designing to transfer power to habitat, Rover, Orbiter, and Rover using E-Orbit. Support for deep-space mission and robotic mission using E-Orbit.

Chapter 6: Conclusion: Summarized the findings of the studies by general conclusions and future scope of Energy orbit.