Important Issues to be Considered in the SSPS Road Map

- In the Case of Tether SSPS -

Original Version: December 2016
English Version: June 2017
Road map is required to facilitate the research and development of SSPS, as a proposal from the SSPS community to the public.

Basic Requirements

1. A clear and specific goal
2. A common target in the SSPS community
3. High technical feasibilities
4. Goal within 30 years
5. Go/no go decision at the major milestones based on objective evaluation
1. A clear and specific goal

Target needs to be illustrated so that the non-expert people can easily understand the concept and principle of operation. Variety of illustrated ideas can not be the target.
Examples of SSPS System Design
- Typical model needs to be selected as a target for the SSPS road map -

**Microwave**

- Solar Power Satellite
  - Non-concentrator
    - Bus Power
    - Distributed Power
  - Concentrator
    - Bus Power
    - Distributed Power

**Laser**

- Laser Direct Excitation

Target selected in this paper
What is the Tether SSPS?

- Background and history -

SPS 2000, designed around 1990 by the SPS 2000 Task Team led by M. Nagatomo

High priority on technical feasibility.

Absorption of the idea "power generation/transmission panel (sandwich panel)"

Designed early in 2001 for commercial use

UseF SSPS Study Team (Prof. Y. Kaya)

NASA Reference System in the 1970's

Highly challenging, lack of technical feasibility

Designed in 2006 and 2007

UseF SSPS Study Subcommittee (S. Sasaki)

antithesis

Small scale
Simple (no attitude control, no movable mechanism)
Low earth orbit

Large scale
Complex (Attitude control & movable mechanism)
Geo-synchronous orbit

Single bus type

Designed in 2002 for demonstration

Highly modular structure and high flexibility

Multi-bus type

Designed in 2001 and 2003 for commercial use

Designed in 2001 for commercial use
2. A single and common target in the SSPS community should be selected.

Since SSPS is a long-future concept, many targets can exist at this stage, depending on design philosophies. Also, uncertainties are extensively included in the targets. A target having essential elements in common should be selected.
Tether SSPS: common/basic part of Sandwich type SSPS

Sun tracking mechanism (mirrors)
Attitude stabilization by gravity gradient force using tethers
Sandwich panel (power generation and transmission panel)

Basic Part
Tether SSPS (Basic Model)
3. High technical feasibilities

A high level of technical feasibility needs to be shown for the target and its way in the roadmap. Otherwise, the roadmap is regarded as a science fiction.
Feasibility Analysis Required for SSPS Model

SSPS feasibility needs to be demonstrated so that majority of experts in the fields of energy and space development recognizes its possibility as the future energy system.

Weight
- Realistic weight as a space infrastructure?

Structure
- Technological feasibility as a space facility?

Feasible thermal design for high power radiation system?

Social acceptability
- Acceptable from the standpoints of biological effects, environmental effects, and impact to the existing infrastructure?

Power system
- Useful and practical power system (power characteristics, reliability, cost)?

Realistic construction scenario using plausible space transportation system in the future?
Realistic weight as a space infrastructure?

- Weight should be estimated based on detailed design and physical models -

Sub-module: 0.5m x 0.5m x 0.02 m, Weight: 1.060 kg
Microwave Circuit (Controller, Power supply, Antenna, 55.5 W): 277.5 g (5 g/W)
Solar Cell (including cables, 118.1 W): 120 g (1.016 g/W)
Batteries (362.5 Wh): 517.9 g (700Wh/kg)
Structure (Honeycomb, Mechanism, Others): 144.6 g (0.029 g/cc)
Technological feasibility as a space facility?

- Feasibility should be demonstrated by design and past achievements -

Space Tether Experiments, Takeo Watanabe et al., ISTS 2009. Chart includes planned experiments. Tethers more than 5 km have been demonstrated several times.
Feasible thermal design for high power radiation system?

- Thermal analysis based on SSPS design -
  (predictable within 10 %)

Temperature of circuits can be kept from $-40 \degree C$ to $+60 \degree C$
Realistic Construction Scenario?
- A practical and feasible scenario for space transportation and assembly in space needs to be shown.
Useful and practical power system?
– Conformity with power demand needs to be ensured–

Power generation varies with local time

The time-varying power supply can conform with daily variation of power demand so long as the SPS power is less than 10% of the total demand.

Advanced type of Tether SSPS has batteries to level off the output power. Since the variation is periodic and predictable, required storage capacity is much less than the ground solar power plant.

<table>
<thead>
<tr>
<th></th>
<th>Module Power</th>
<th>Total Power</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar Power</td>
<td>1,350 W(max)</td>
<td>8.0 GW</td>
<td>Module size 1m², x0.92 in summer and winter (0.97 on average)</td>
</tr>
<tr>
<td>Power Generation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Peak)</td>
<td>473 W(Upper)</td>
<td>2,8 GW(Upper)</td>
<td>Solar cell area of lower plane is 90% of the upper plane.</td>
</tr>
<tr>
<td></td>
<td>425 W(Lower)</td>
<td>2,5 GW(Lower)</td>
<td>Solar cell efficiency 35%</td>
</tr>
<tr>
<td>Power Storage in</td>
<td>1000 Wh</td>
<td>5.9 GWh</td>
<td>Flat power output 60% Charge/discharge efficiency 90% Charging only when more than 25% of peak power</td>
</tr>
<tr>
<td>Batteries</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power to Transmitters</td>
<td>270 W</td>
<td>1,6 GW</td>
<td></td>
</tr>
<tr>
<td>Power Transmission</td>
<td>228 W</td>
<td>1,4 GW</td>
<td>DC/RF conversion efficiency 85%</td>
</tr>
<tr>
<td>Rectenna Input</td>
<td>–</td>
<td>1,2 GW</td>
<td>Transmission 97%, Collection 90%</td>
</tr>
<tr>
<td>Rectenna Output</td>
<td>–</td>
<td>1 GW</td>
<td>RF/DC conversion 85%</td>
</tr>
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4. **Goal must be within 30 years**

Target more than 30 years from now has no reality. It is regarded as a dream. Dream is not invested in. The budget for dream is limited to academic research.
A Scenario for SSPS Realization in 30 Years
- Comparison with Nuclear Fission and Fusion -

Nuclear Fission Plant (History)

- 1942: Critical Nuclear Chain-reaction Success
- 1951: First Electricity from Nuclear Reactor (200kW)
- 1960: Commercial Light Water Reactor (180MW, GE)

Nuclear Fusion Plant (Plan)

- 2025: Fusion Verification (Q > 10)
- 2035: Proto Model Reactor
- 2045-50: Commercial Phase

Space Solar Power Systems (Plan)

- 2020: On-orbit Verification
- 2025: Initial End-End Verification (100kW)
- 2030: Plant (2MW)
- 2035: Plant (200MW)
- 2040: Commercial SSPS (1GW)

Way to go for SSPS realization
Future of Space Transportation Expected for SSPS

Long-term Vision for Space Transportation System (Draft), Office of Japan National Space Policy, predicts operation in 2040’s for SSPS construction.
5. Go/no go decision should be made at the major milestones based on objective evaluation.

Objective evaluation at each development phase assures the project is promoted for general public, not for SSPS community.
Research Phase

- Ground demonstration
- Small-scale on orbit demonstration
- 100kW class on orbit demonstration

Development Phase

- 2MW class demonstration
- 200MW class plant

Commercial Phase

- 1GW class first commercial model
- Commercial SSPS (1SSPS/year)