# Construction Scenario for Tethered Solar Power Satellite

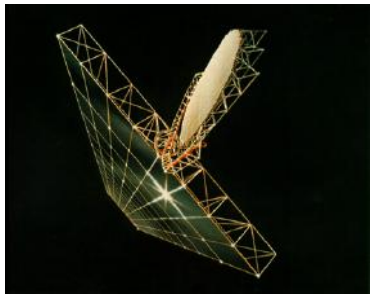
- Concept of Tethered-SPS
- Typical Characteristics
- Construction Scenario
- Development Scenario

IAC Valencia, October 2006

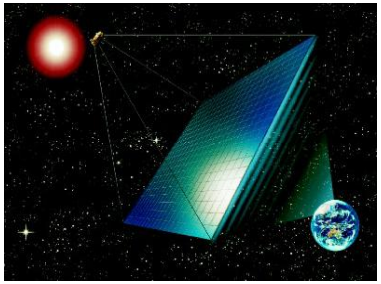
# Classification of SPS Models and Typical Examples of SPS

Solar Power Satellite

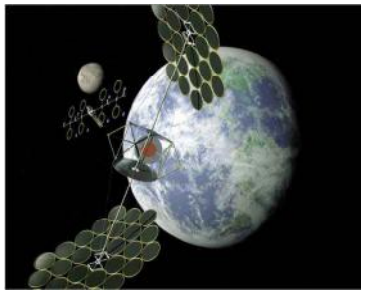
- Non-concentrator
  - Bus Power
  - Distributed Power
- Concentrator
  - Bus Power
  - Distributed power



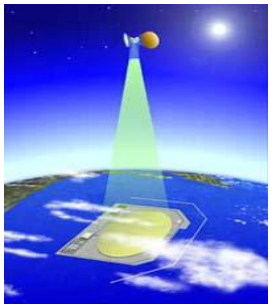
NASA Reference Model[2]



Tethered-SPS[3]



NASA ISC[4]



NASDA2001 Model[5]

# Why "Distributed Power without Concentrator"

Concentrator Type SPS using Large Reflecting Mirrors:

to reduce the size of solar array panel

steering mirror concept hardly realized because of its complicated configuration and the over-heat problem of the solar array panel

Non-Concentrator Type SPS with Bus Power:

unacceptable weight of the power collection cables

unfeasible technologies for the rotary joint mechanism

Non-Concentrator with Distributed-Power:

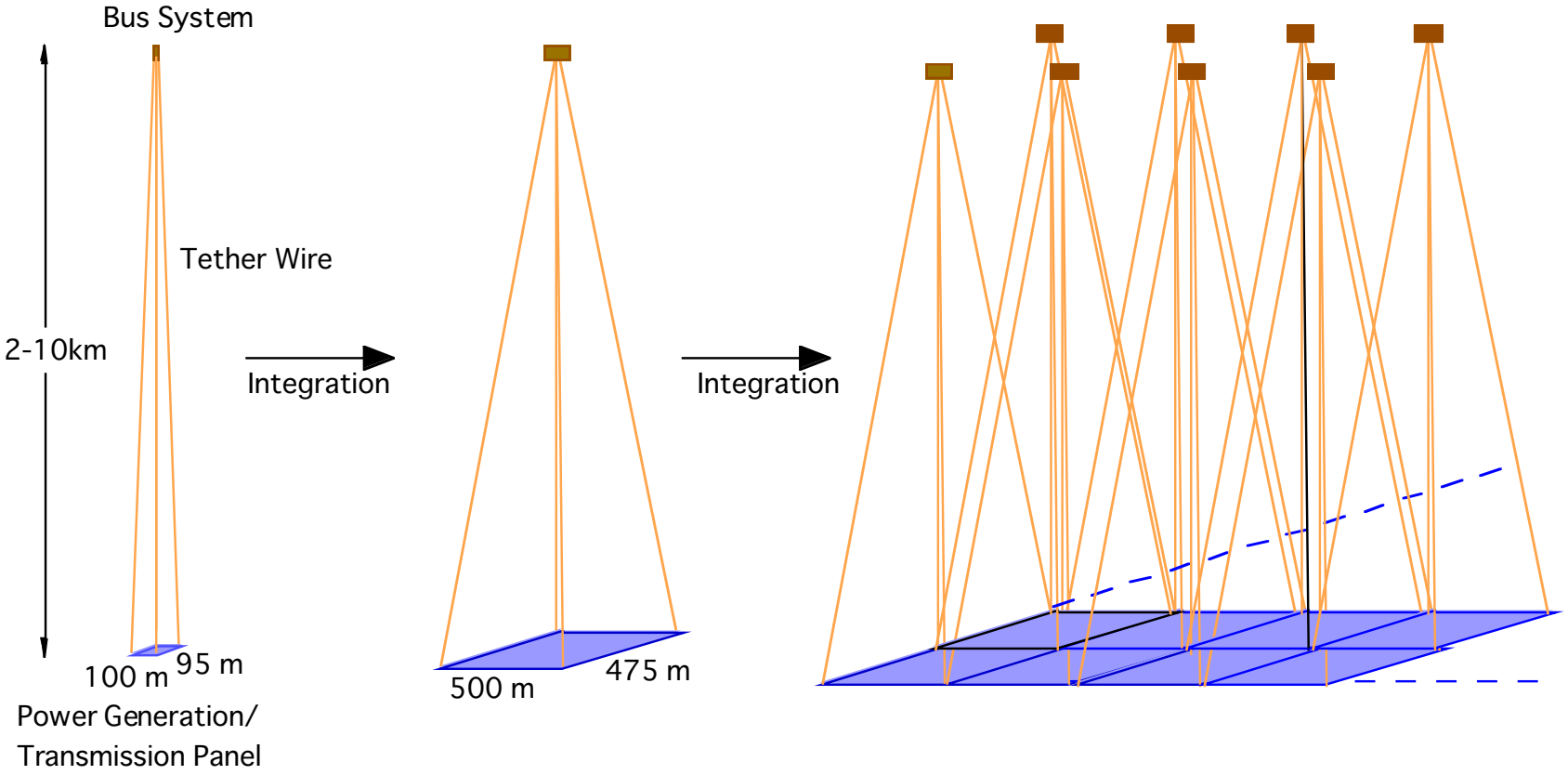
total power efficiency is 36 % lower than that for the sun-pointing type

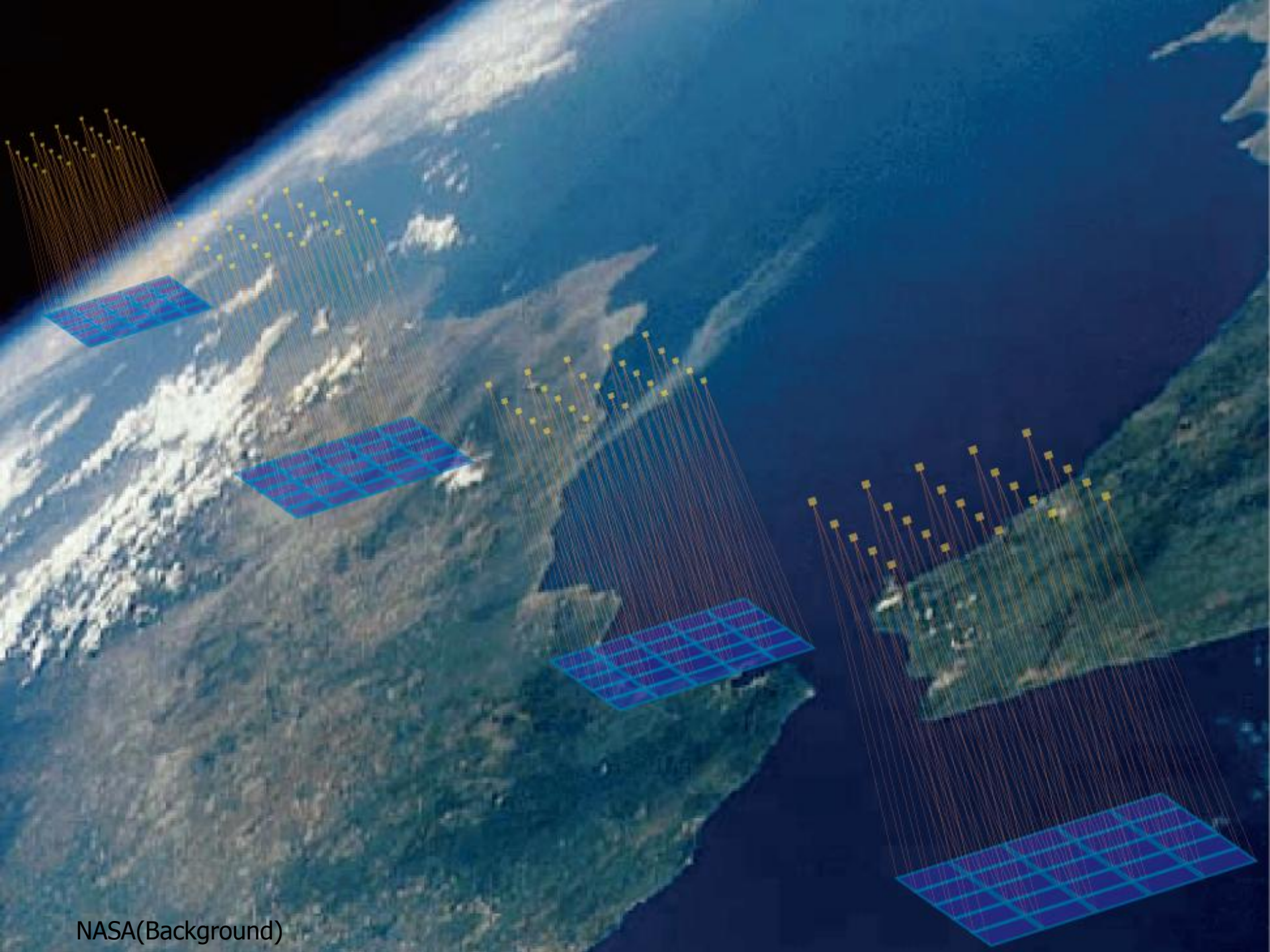
only model that has no critical difficulties based on the existing technologies

the simple, technically feasible, and practical configuration resolves almost all the technical problems in the other SPS models.

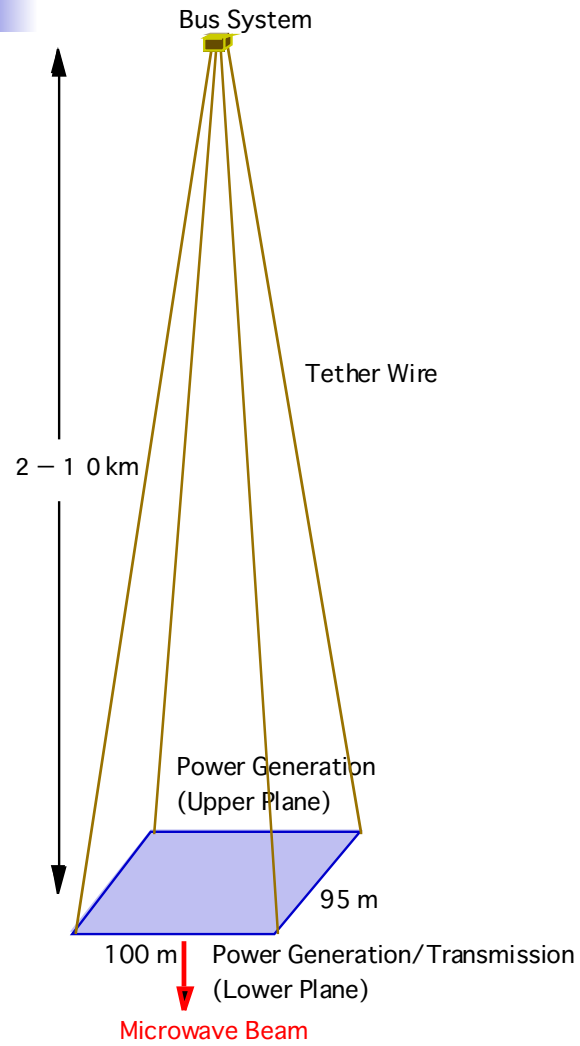
# Concept of Tether SPS (Constant Output)

Total Weight: 26,500 MT Output Power: 1 GW(constant)




NASA(Background)

# Unit of Tethered-SPS with Existing Technologies

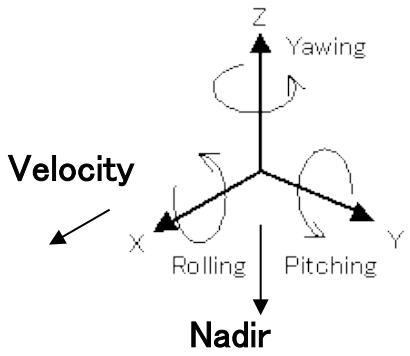



| Basic Technology | Technology Level |
|---|---|
| Space tether Technologies (2~10km) | Deployment of tether more than 4 km have been conducted 5 times so far; SEDS-1(20km,1993), SEDS-2(20km,1994), TSS-1R(20km, 1996), TiPS(4km,1996), ATEx(6km, 1999) |
| Deployment of large panel (100mx100m) | Solar array paddle 4.6mx32m(2000) |

# System Characteristics of Tethered SPS (Constant Power)

| | |
|---|---|
| Configuration | Power generation/transmission panel suspended by 100 wires |
| Panel size | 2.5 km x 2.375 km x 0.02 m |
| Number of sub-panel | 25 (5x5) |
| Tether wire length | 2.5 km approx. |
| Bus separation | 356 m (8° ) |
| Total weight | 26,600 MT (Panel 25,200 MT, Bus 1,400 MT) |
| Sub-panel | Power generation/transmission panel suspended by 4 wires (internal 96 wires are slacked) |
| Size & weight | 500 m x 475 m x 0.02 m, 1010 MT |
| Unit/sub-panel | 25 (5x5) |
| Tether tension | 54 gw per wire |
| Unit panel | Power generation/transmission panel suspended by 4 wires |
| Size & weight | 10 m x 95 m x 0.02m , 40 MT |
| Module number/unit panel | 3,800 (20x190) |
| Tether tension | 2 gw per wire |
| Power transmission | 2.1 MW |
| Module | Power generation/transmission panel |
| Module size & weight | 5 m x 0.5 m x 0.02 m, 10.625 kg |
| Power generation | 1,181 W max (1,350x0.85) |
| Power transmission | 555 W constant (473x095x0.97x0.6x0.85) |
| Output Power | 1 GW constant (rectenna DC output), 5.8 GHz |

# Attitude Stability of Tethered-SPS




Amplitude of attitude fluctuation induced by solar radiation pressure when deviation between the center of gravity and the center of shape is 1 %.

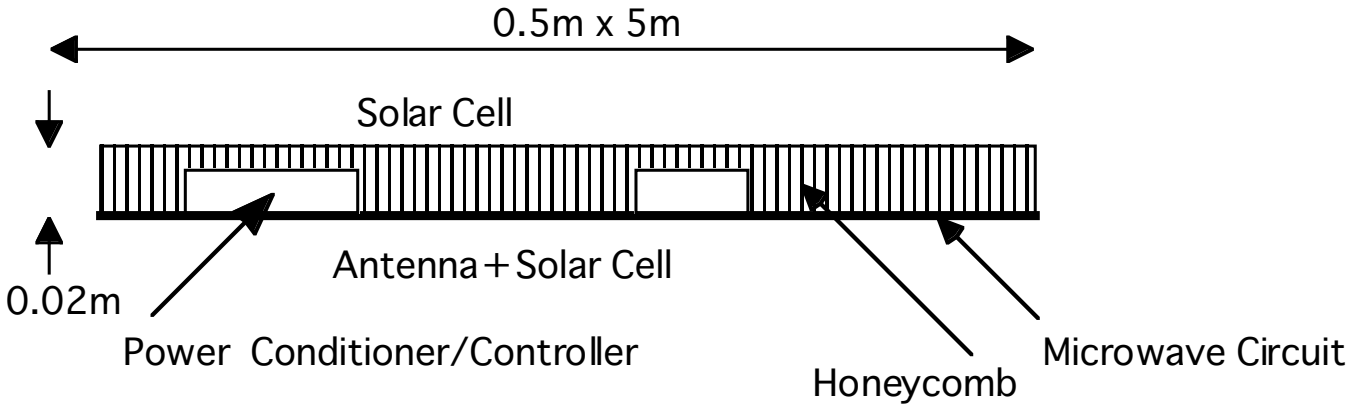
| Direction of Fluctuation | Amplitude [rad] |
|---|---|
| Pitch angle by disturbance along pitch axis | $2.8 \times 10^{-3}$ (0.16 degrees) |
| Roll angle by disturbance along roll axis | $1.3 \times 10^{-4}$ |
| Yaw angle by disturbance along roll axis | $1.2 \times 10^{-4}$ |
| Roll angle by disturbance along yaw axis | $5.8 \times 10^{-5}$ |
| Yaw angle by disturbance along yaw axis | $2.4 \times 10^{-3}$ |

Ishimura (Hokkaido Univ.) 2005

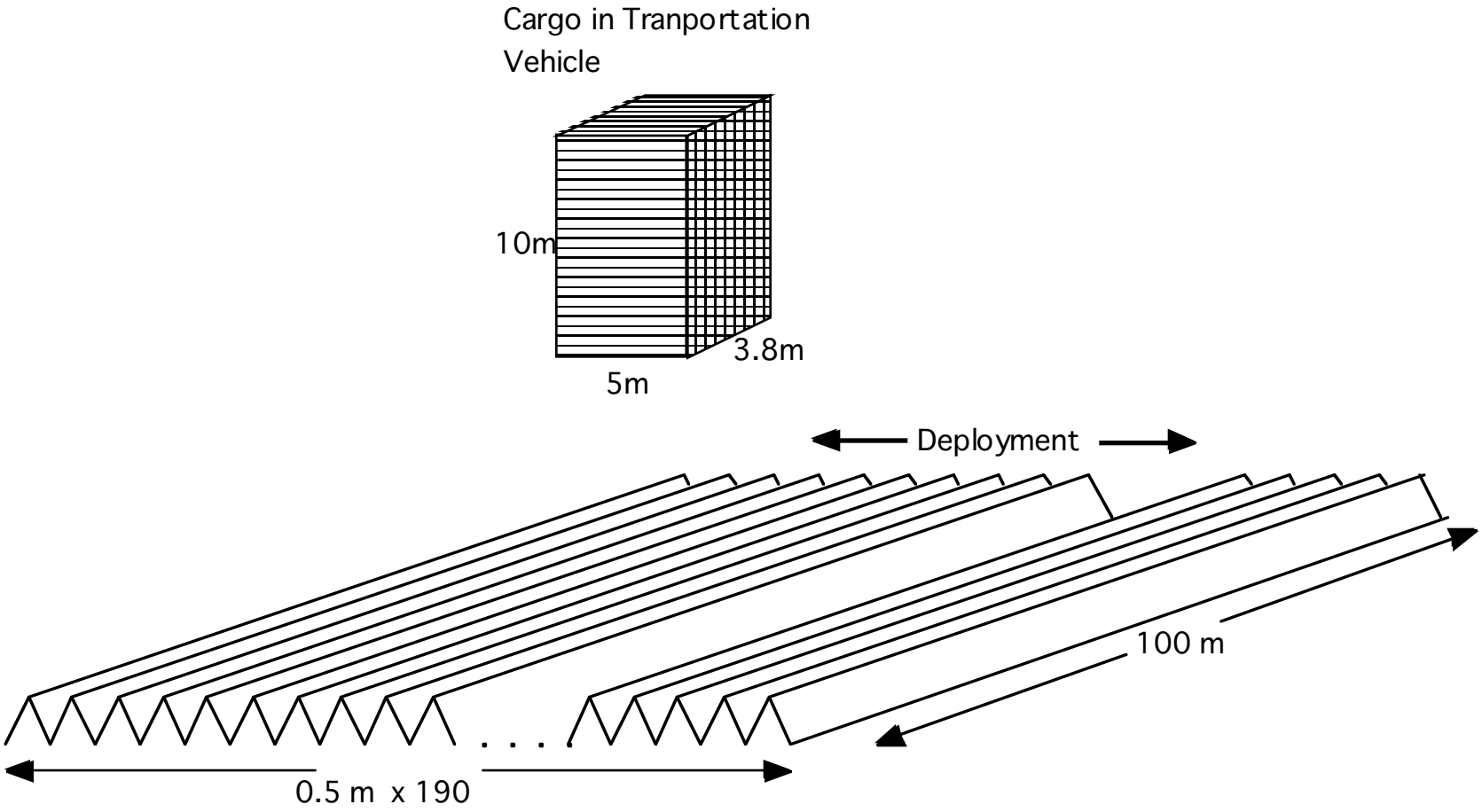
# Module Structure（constant power type）

- Power generation and transmission panel is composed of perfectly equivalent modules.
- Power generated by the solar cell is converted into microwave power in a module.
- All modules are controlled by wireless LAN.

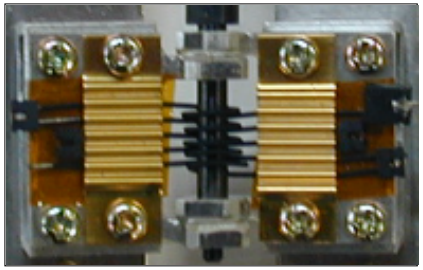
⇨No power/signal cabling between the modules.
⇨ Robust and low cost (mass production, easy quality control)



# Panel Deployment

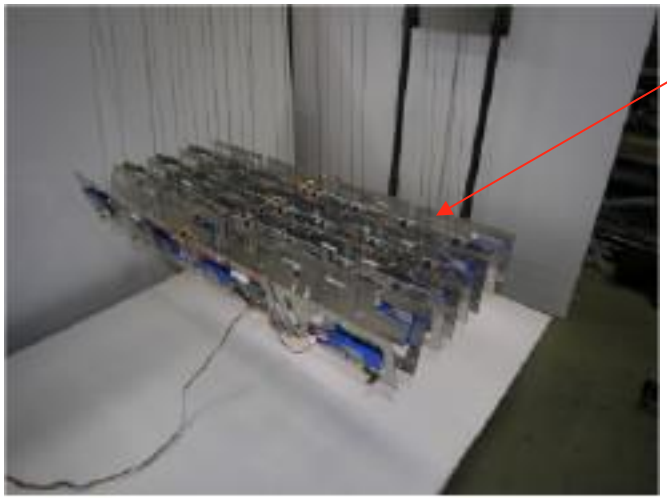


# Deployment Mechanism using SMA (Shape Memory Alloy) Actuators

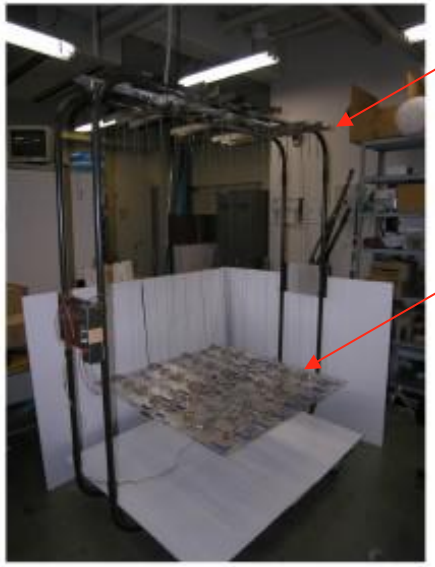


Actuator using shape memory alloy coils

Testing using miniature panel model



32 panels
(23x11cm)

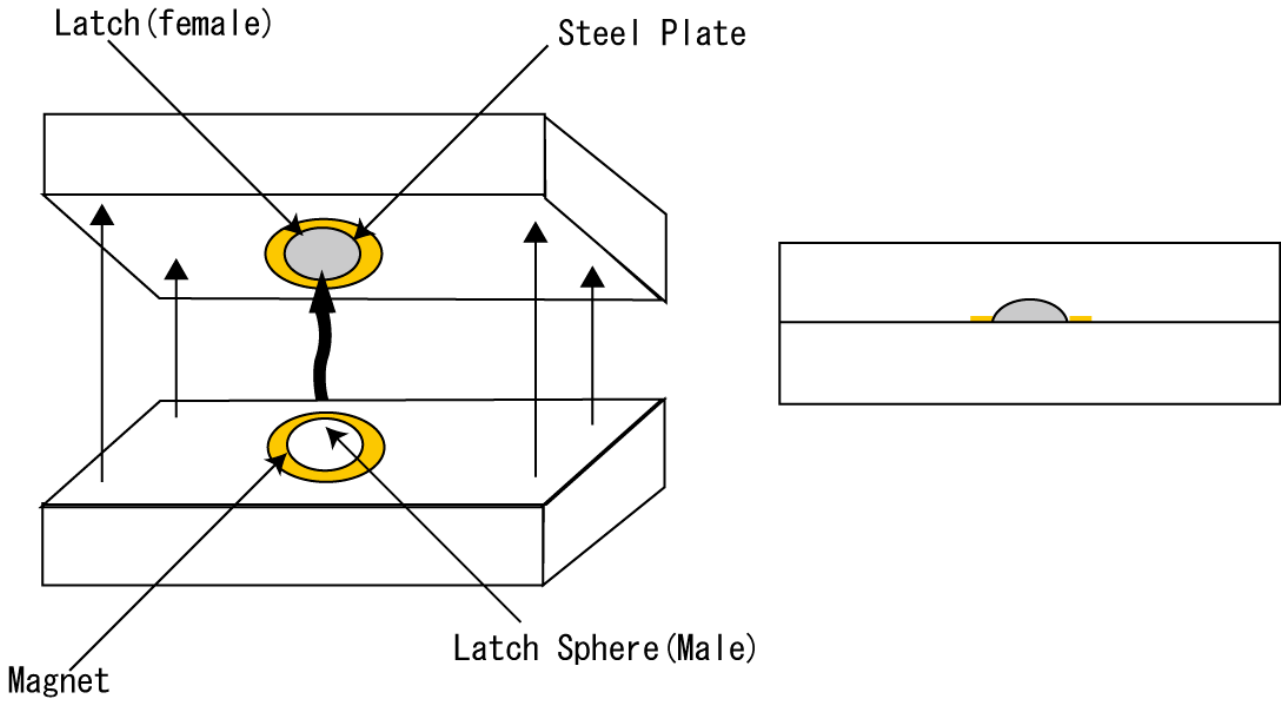


Cancellation mechanism for gravity field

32 panels after deployment

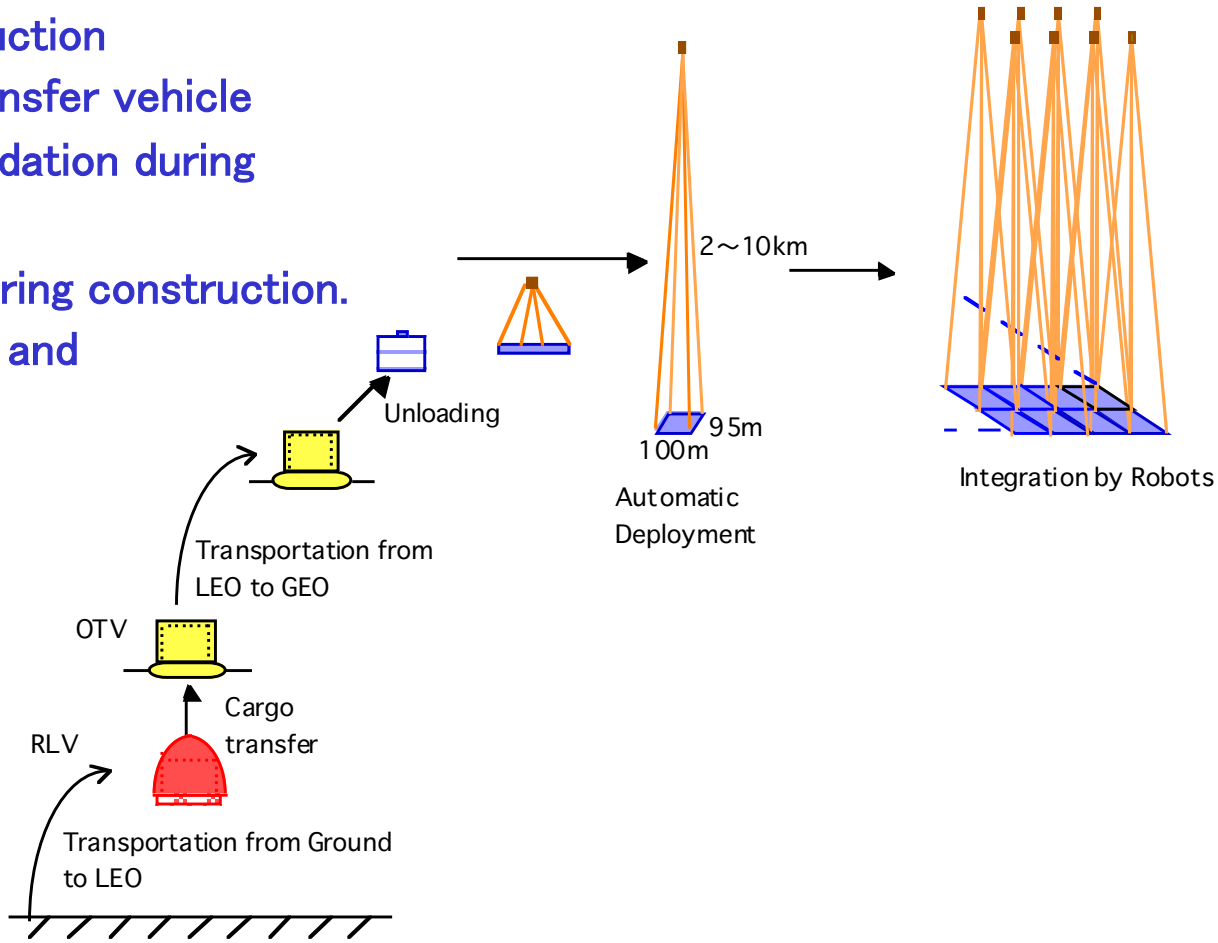
# Connection and Latch using combination of a sheet magnet and a steel plate

Magnet：10mm in outer diameter, 6mm in inner diameter
Connecting Force：1024g/100m（25 cm/connection）

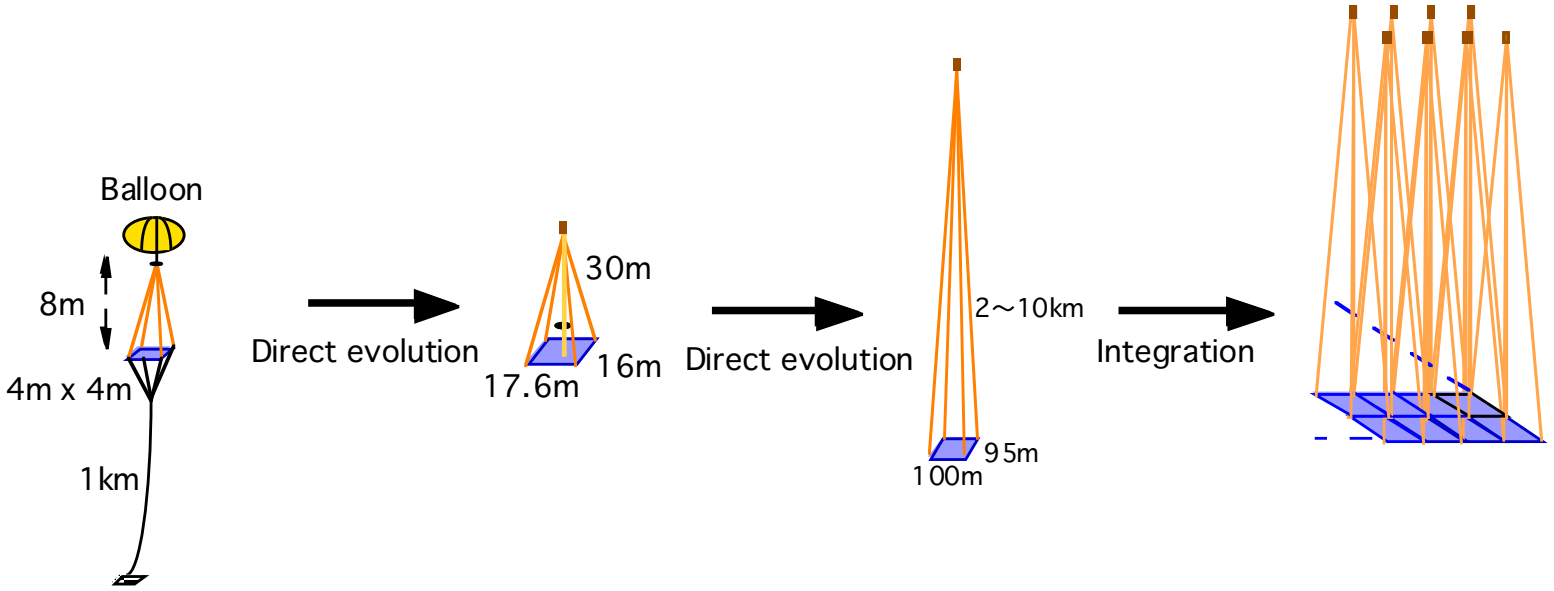


# Construction Scenario

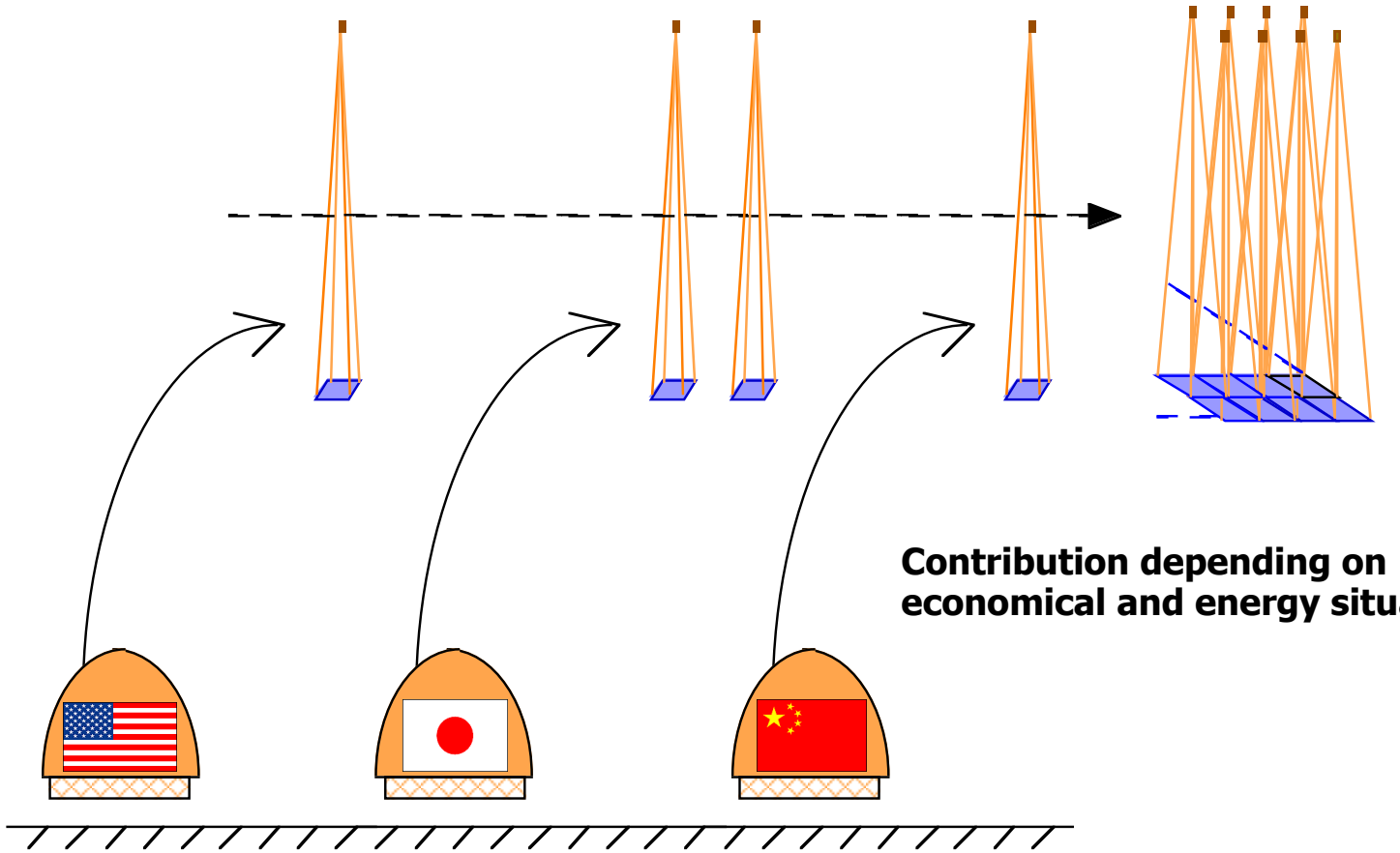
1. Unmanned construction
2. Moderate orbit transfer vehicle
3. No radiation degradation during transportation
4. Full verification during construction.
5. Easy maintenance and scale-up



# Evolution from Demonstration Model to Practical Model (Type B)

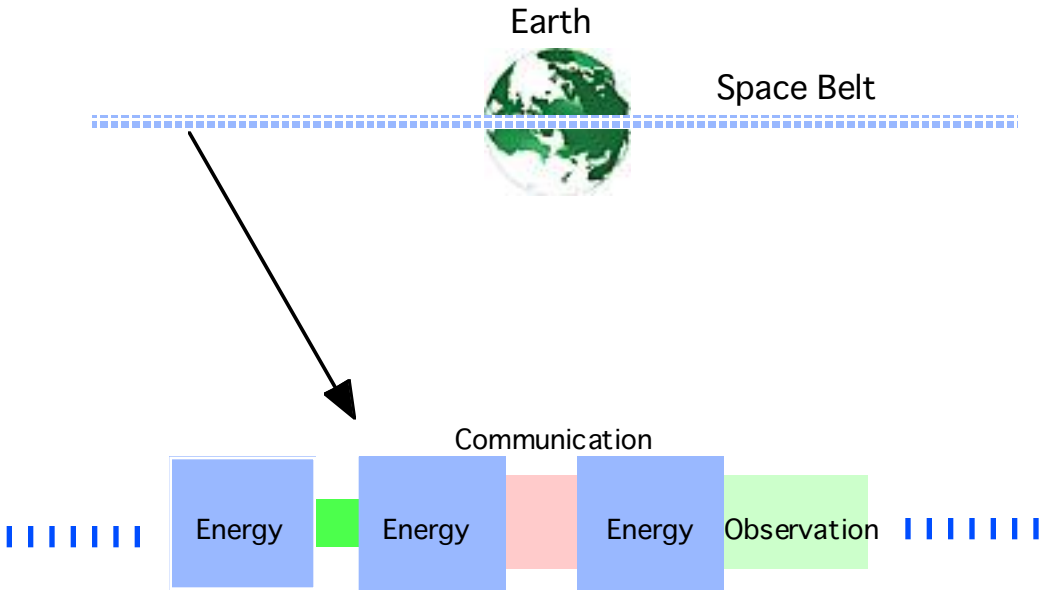


# Easy Investment with Clear Work Interface



**Contribution depending on economical and energy situation.**

# Coexistence with Other Geo-stationary Satellites




Complex of facilities for Energy, Communication, Earth Observation, Space Telescope, Space Experiment, and Maintenance in Geosynchronous orbit.

World primary energy(13,000 GW) can be supplied from space belt with the length of 32,500 km (14 % of total space belt).

# Summary and Conclusion

・Tethered-SPS, a distributed-power type SPS without the concentrator, is a highly practical SPS model.

・It is constructed in the geo-stationary orbit by integrating perfectly equivalent units of the Tethered-SPS. Each SPS unit is transported from the ground and deployed automatically in the orbit.

・This construction scenario has many innovative aspects;

- phased construction to guarantee sound development,
- easy integration and maintenance, and
- straightforward development strategy from the demonstration to commercial phase