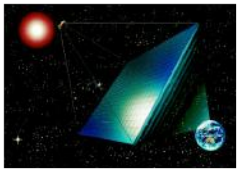
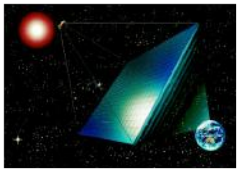


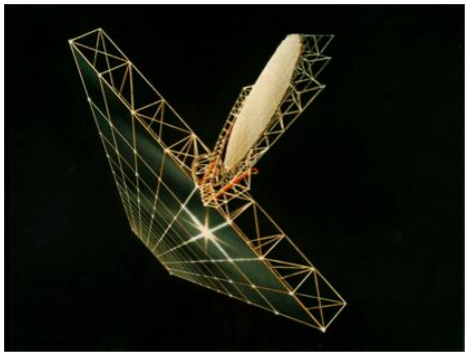
Engineering Research for Tethered-Solar Power Satellite

- Concept of Tethered-SPS
- Engineering Research for the Critical Technologies
  - Automatic Deployment of a Large Panel
  - Design of Power Generation/Transmission Module

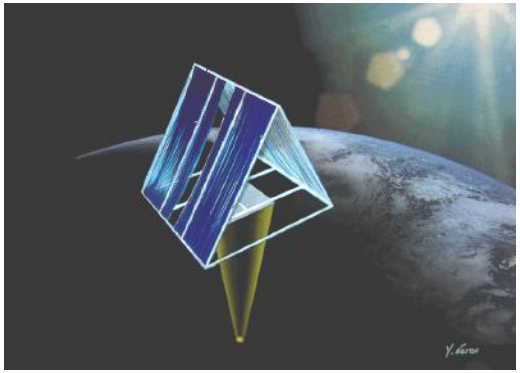
AP-RASC'04
August 2004



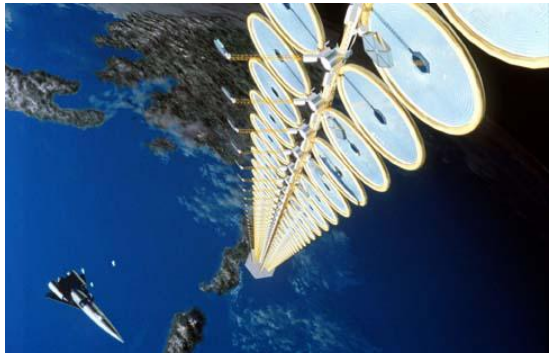
Typical Examples of SPS



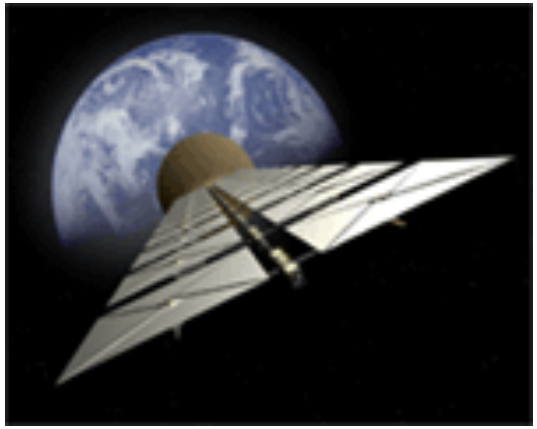
NASA Reference System



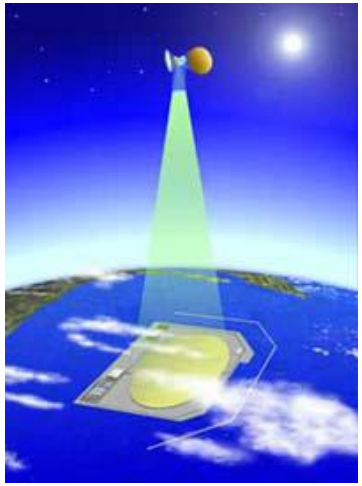
ISAS SPS 2000



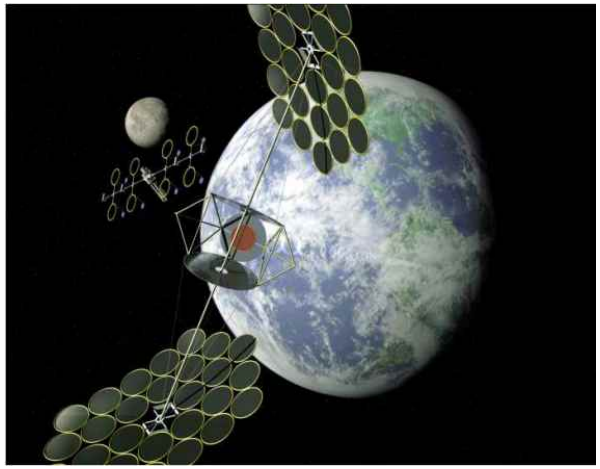
NASA Sun Tower



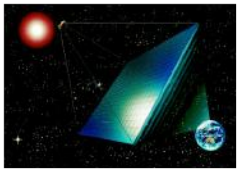
European Solar Sail Tower



NASDA (JAXA) SSPS Model

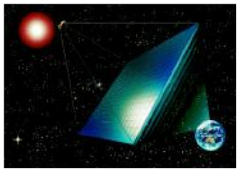


NASA Integrated Symmetrical Concentrator

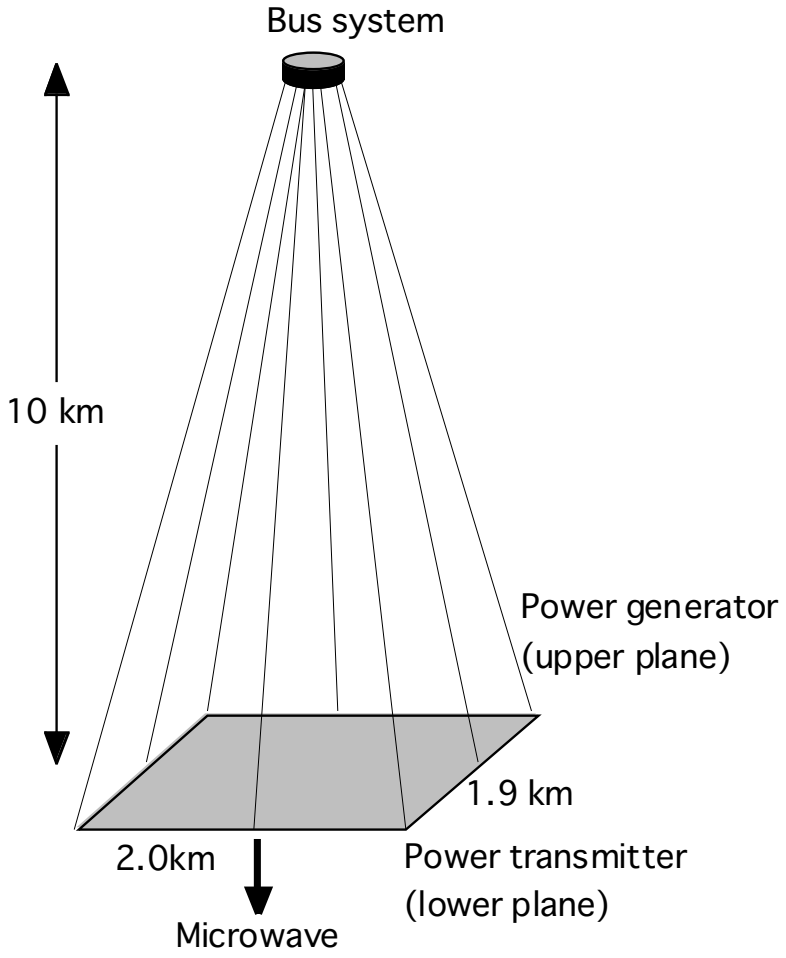


Problem Area in the Past SPS Models

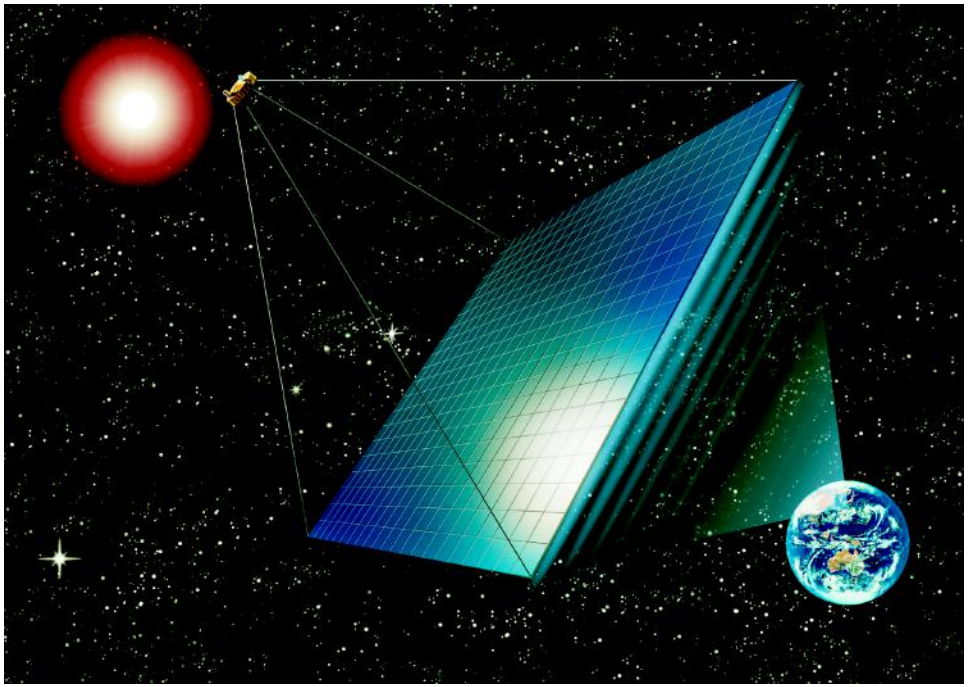
Problem Area	Description
Rotary joint Movable mechanism for rotation mirror	Lack of robustness (no redundancy) Total loss by one-point failure
Power collection cable or Super conduction cable	Huge cable weight Difficult implementation for super conduction
Light condensing mirror	Problem in heat rejection from transmitter Challenging technology in shape and attitude control of large thin film structure
Operation start after full construction	Large investment risk
Construction in LEO and transportation to GEO	Huge size OTV Degradation of semi-conductors by radiation
Independent study on demonstration and commercial SPS	Non consistent strategy in the road map from demonstration model to commercial SPS

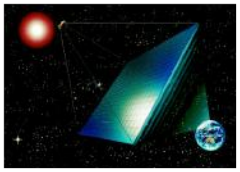


Tethered-Solar Power Satellite

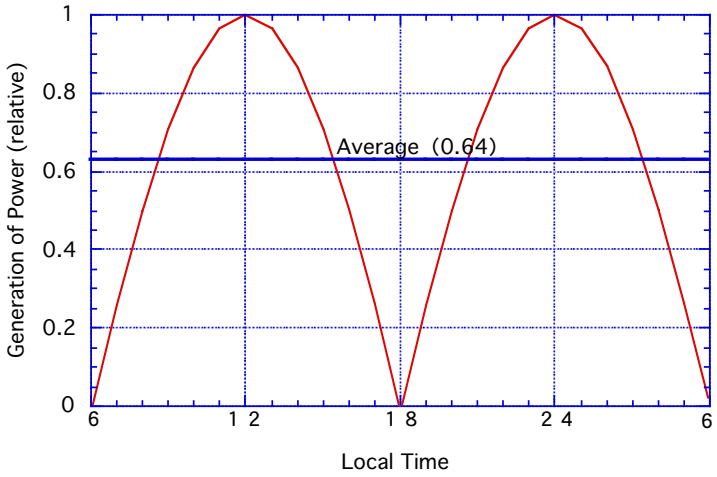


Total weight: 20,000 MT
Output power: 1.2 GW maximum
0.75 GW on average





Characteristic Features of Tethered-SPS

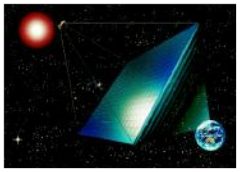


Advantages

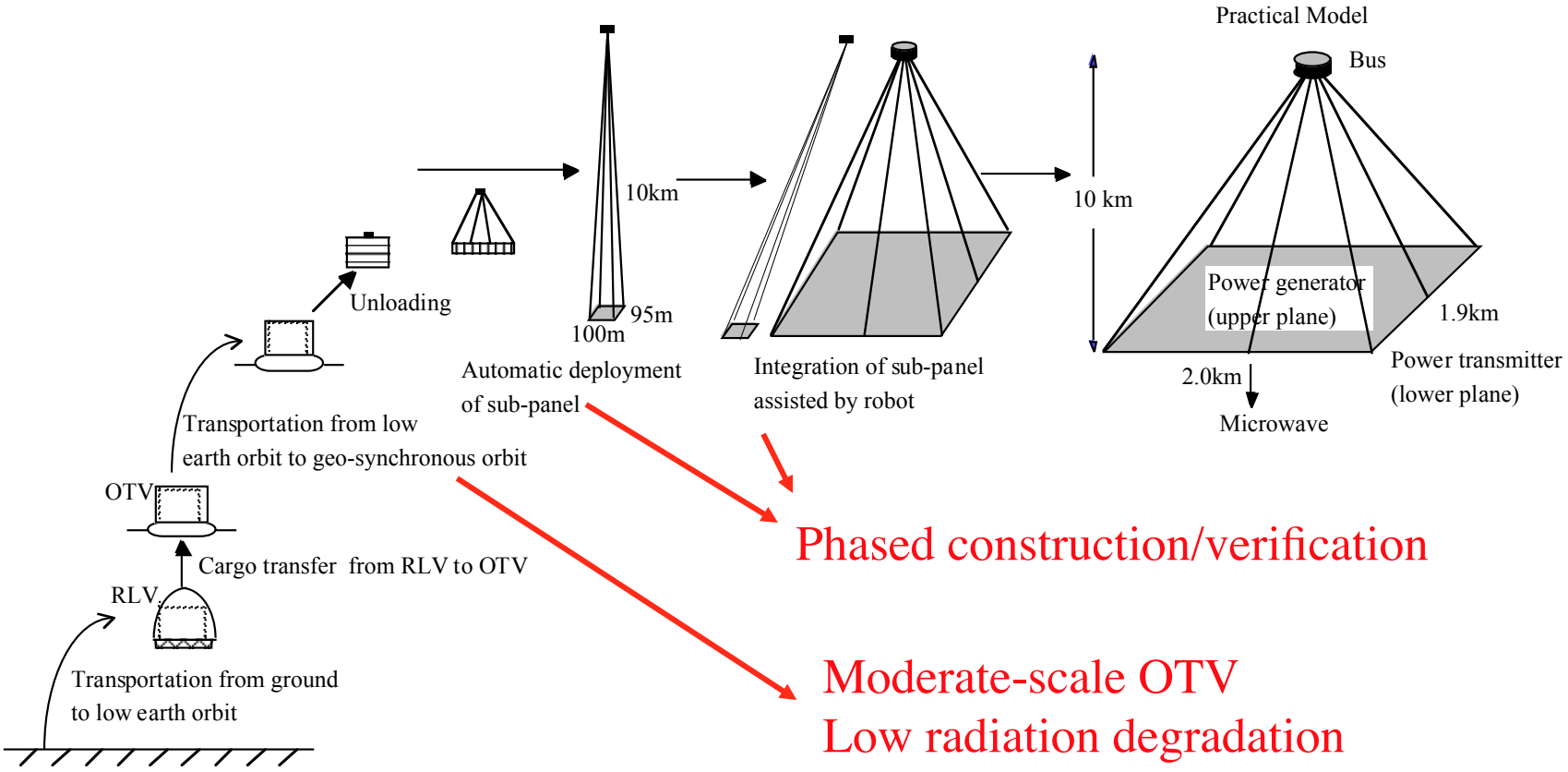
- No active attitude control
- No movable mechanism
- No thermal problem
- Smaller rectenna

Disadvantages

- Variation of power transmission depending on local time(sun angle)
- The power efficiency is 64% as compared with the sun-pointing type SPS.

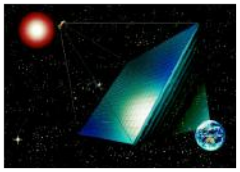


Construction Scenario



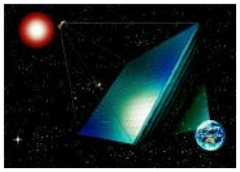
Phased construction/verification

Moderate-scale OTV
Low radiation degradation



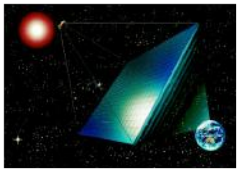
System Characteristics of Demonstration Experiment

Size	40.8m x 17.6m x 16.0m
Total Weight	18,100 kg
Power Generation	36 kW max
Power Transmission	420 kW～140 kW
Beam Control	retrodirective control
Microwave Frequency	5.8 GHz
Operation	full power for 16 sec 10% power for 4 min
System Configuration	panel, truss, tether, weight mass
Panel Configuration	80 foldable panels 400 power modules 250,000 antennas
Attitude Control	gravity gradient force
Altitude	370 km
Rectenna type	parabola collector
Rectenna output	30 kW～10 kW (500 m diameter)

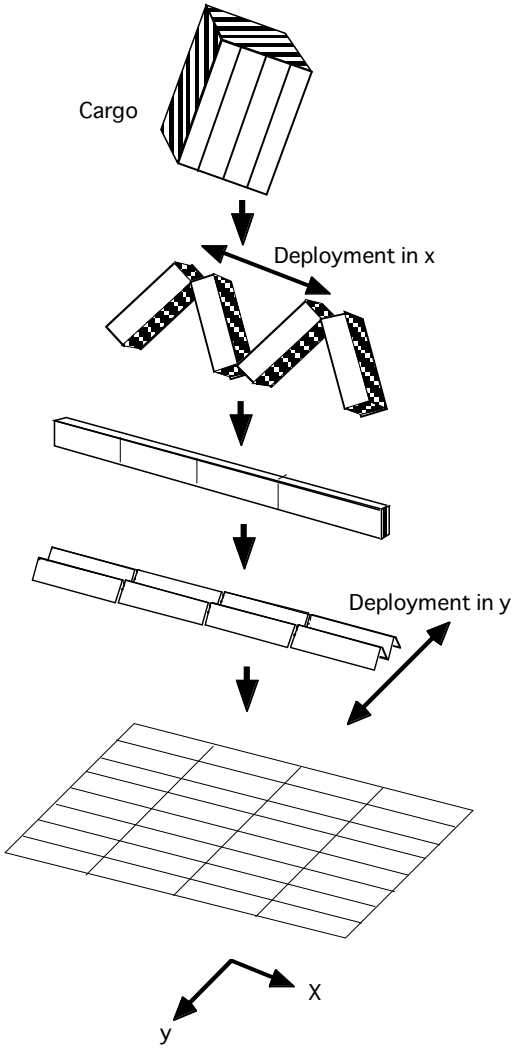


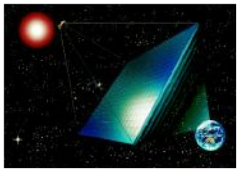
Key Technologies Required for Demonstration Experiment

	Concept Development	Analysis	Verification by experiment
Two-dimensional panel deployment	■		
Attirude & shape control	■	■	
High-efficiency and low-loss microwave transmitter	■	■	■
Retrodirective beam control	■		
Thermal Control	■	■	
Rectenna for low-power density microwave	■	■	

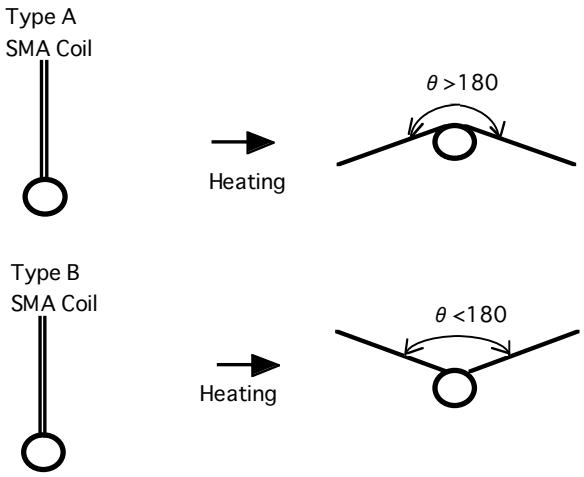


Deployment Sequence of Power Generation/Transmission Panel

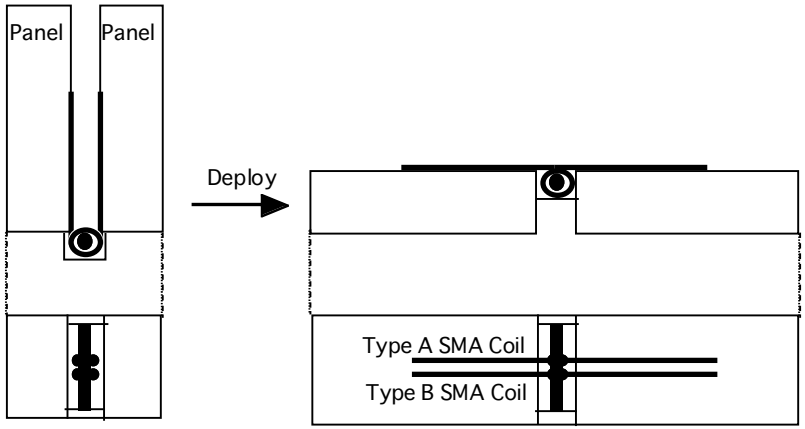




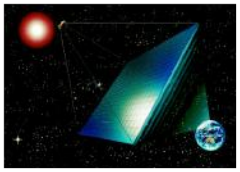
Shape Memory Alloy (SMA) for Actuator



(a)

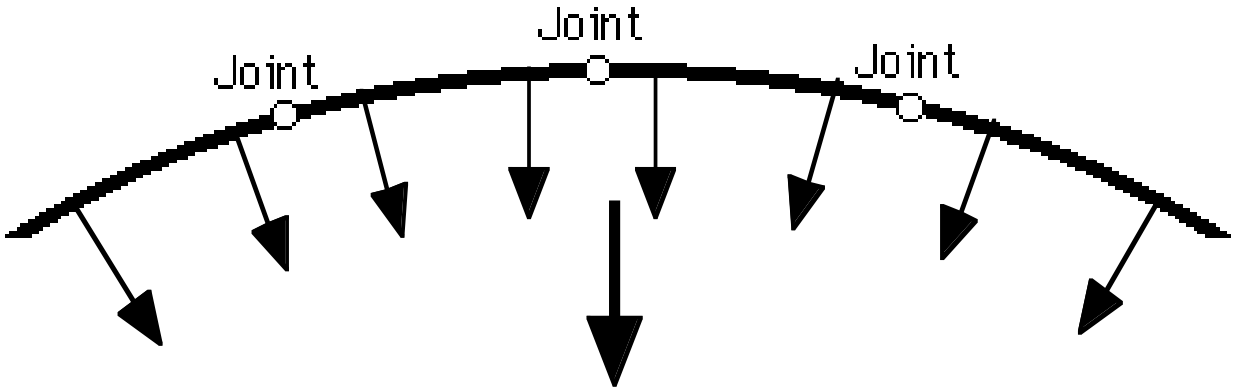


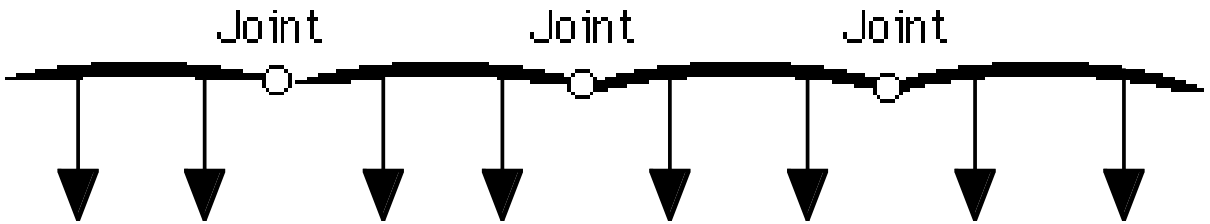
(b)



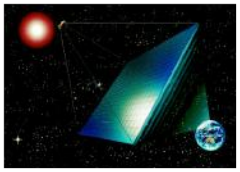
Shape Control of Panel using SMA Joint

Thermal Deformation of Panel Shape

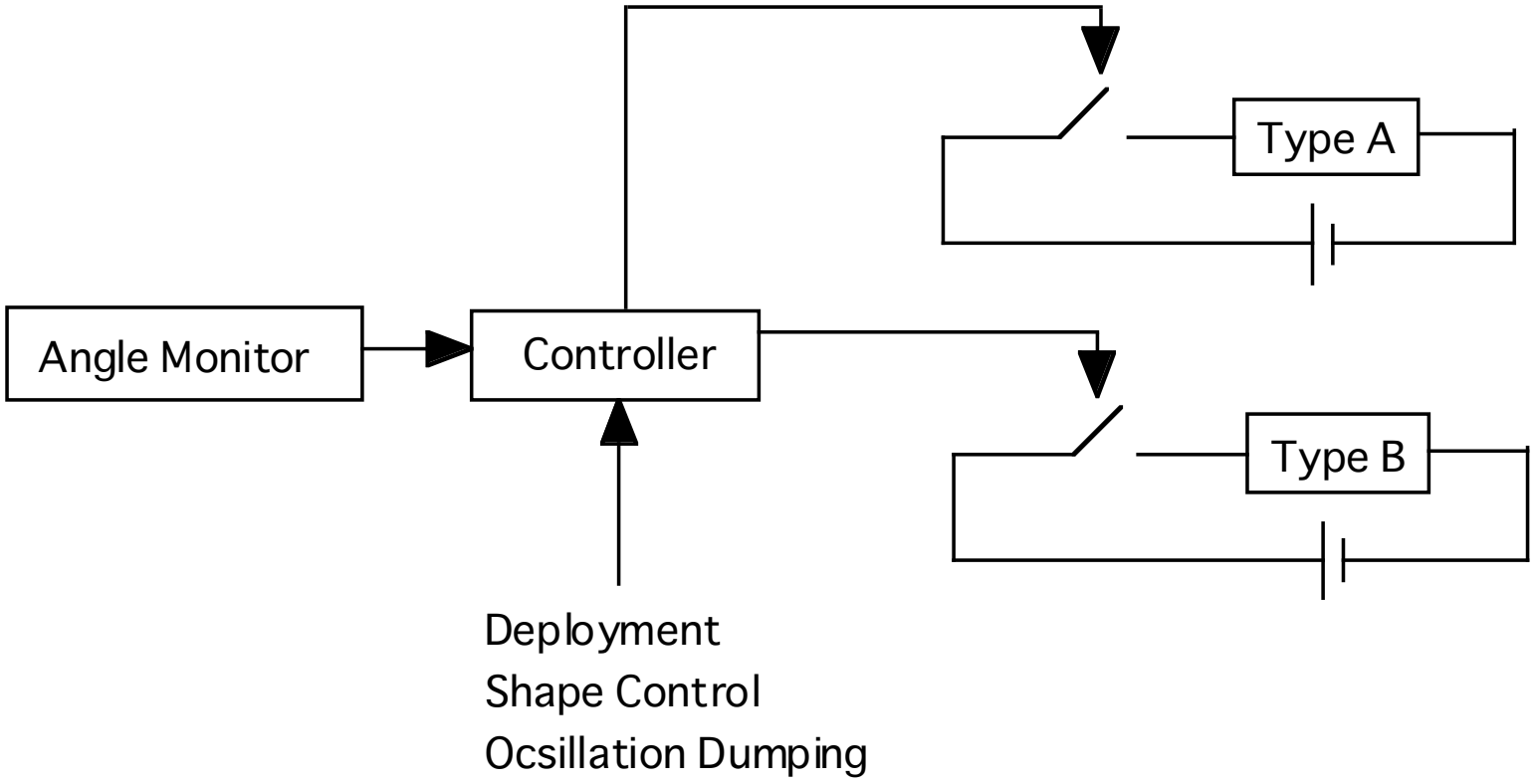




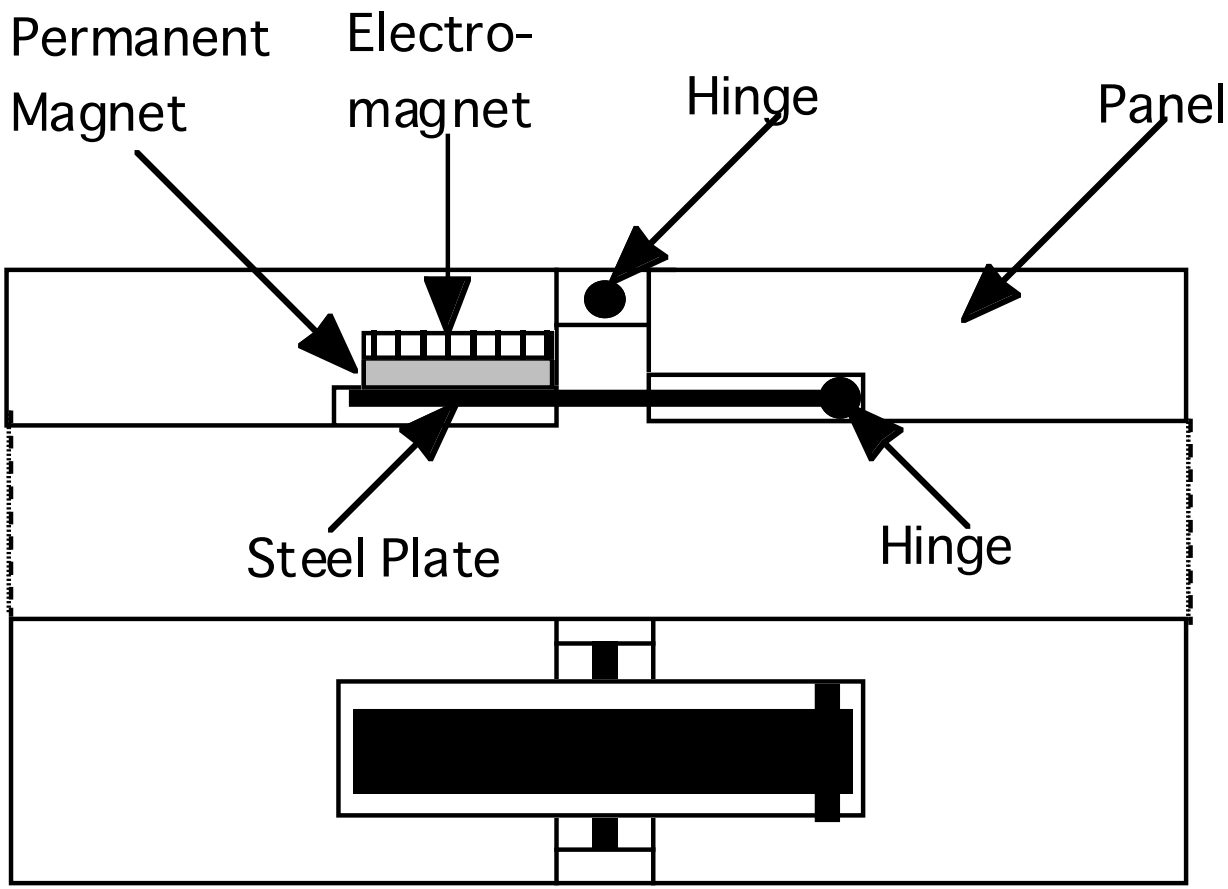
Shape Control by Adjustment of Panel Angle

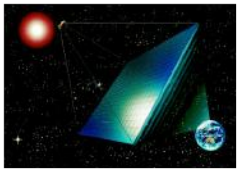


SMA Control for Three Functions

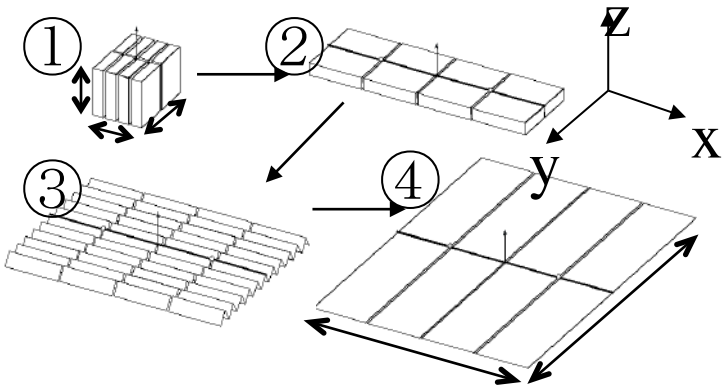


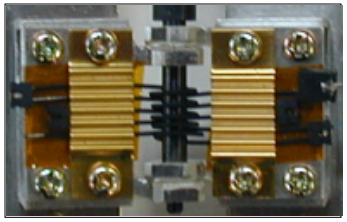
Latch Mechanism

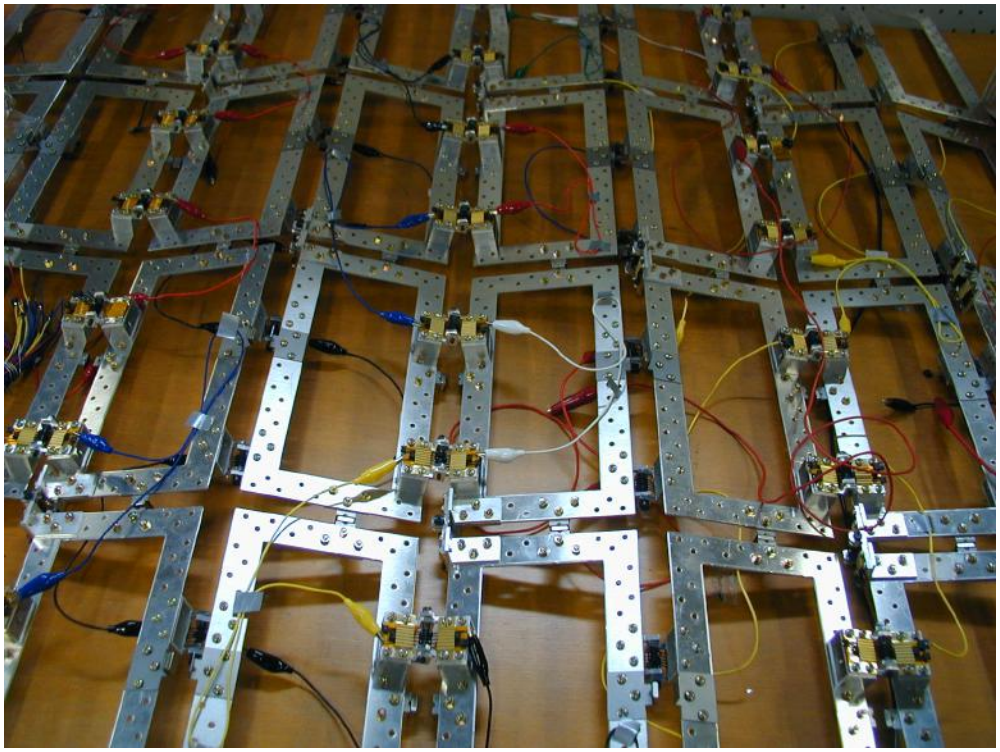


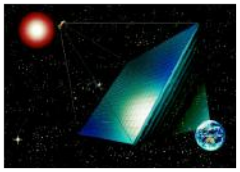


Laboratory Test Model









Concept of Power Generation and Transmission Module

Power generation/transmission panel composing of perfectly equivalent modules

・The power generated by the solar cells of a module is all convertated to microwave.

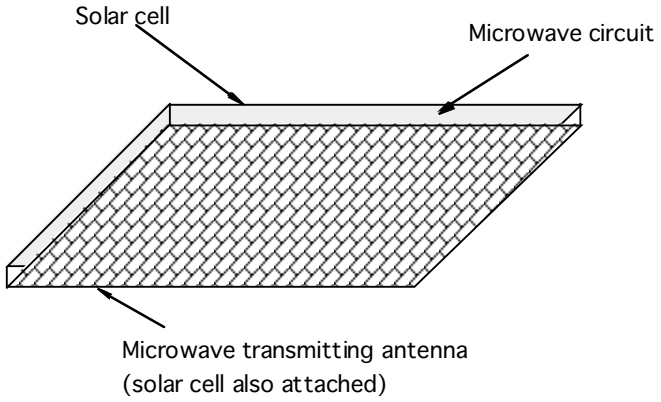
・All modules are controlled by wireless LAN system.

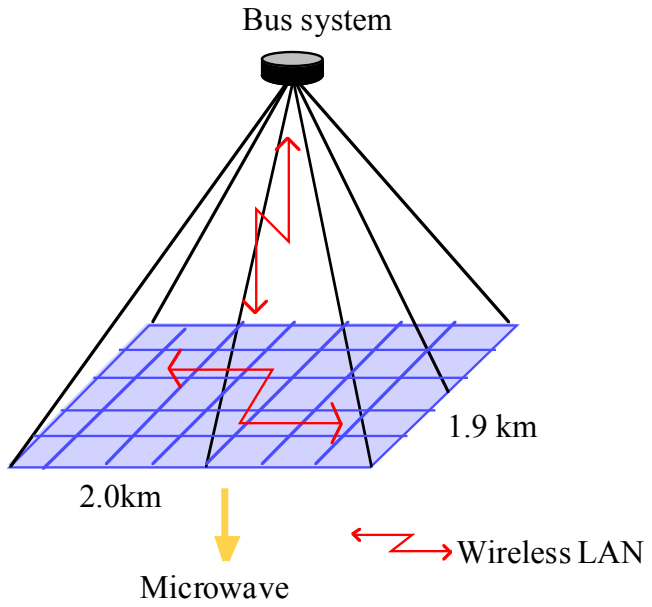
⇨No power/signal cable interface between the modules.

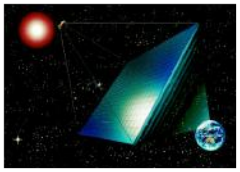
・easy attachment and detachment as a module

・robust as a power system

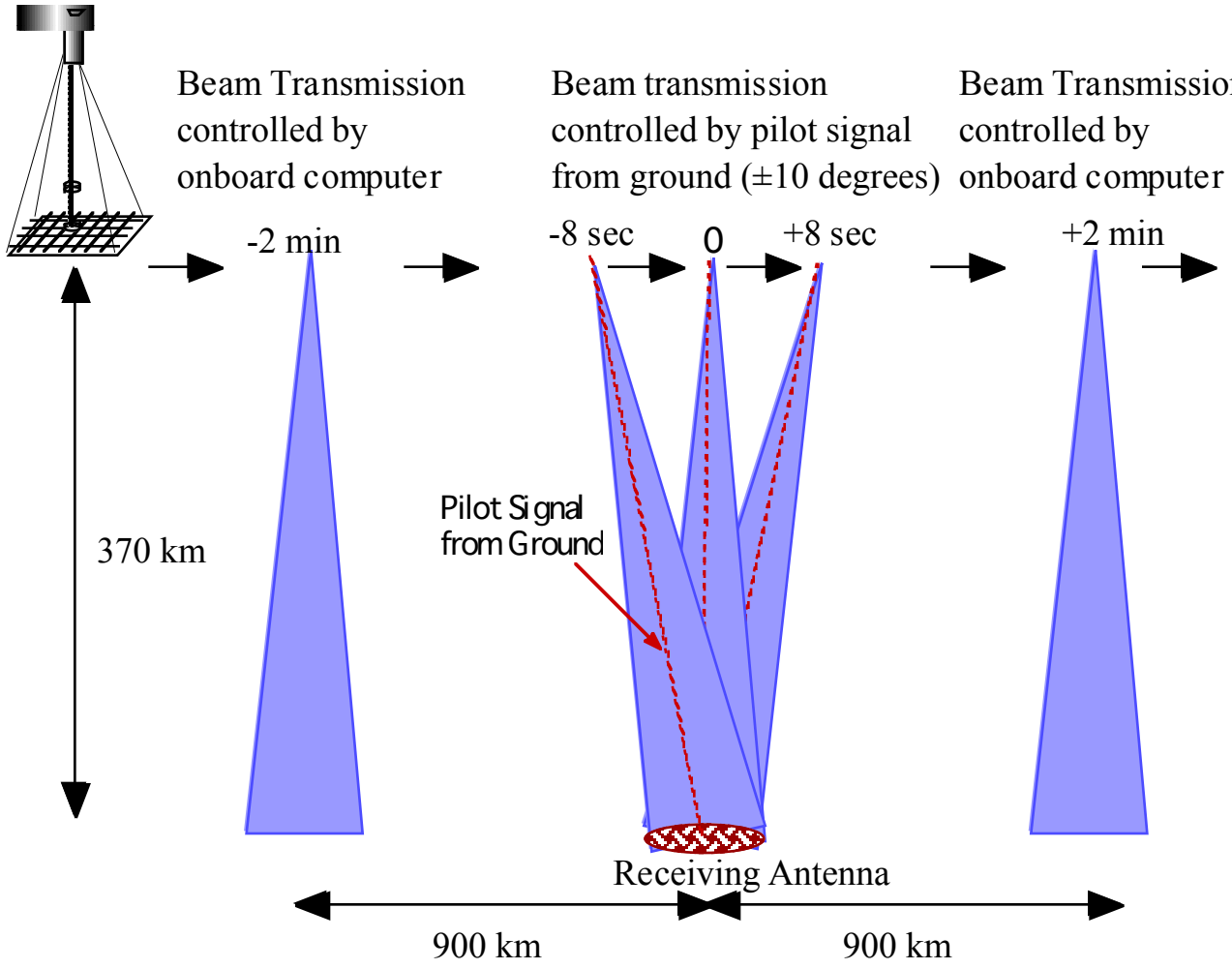
・easy fabrication, test, integration, and maintenance

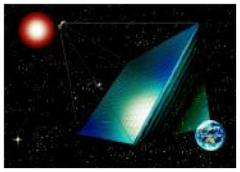




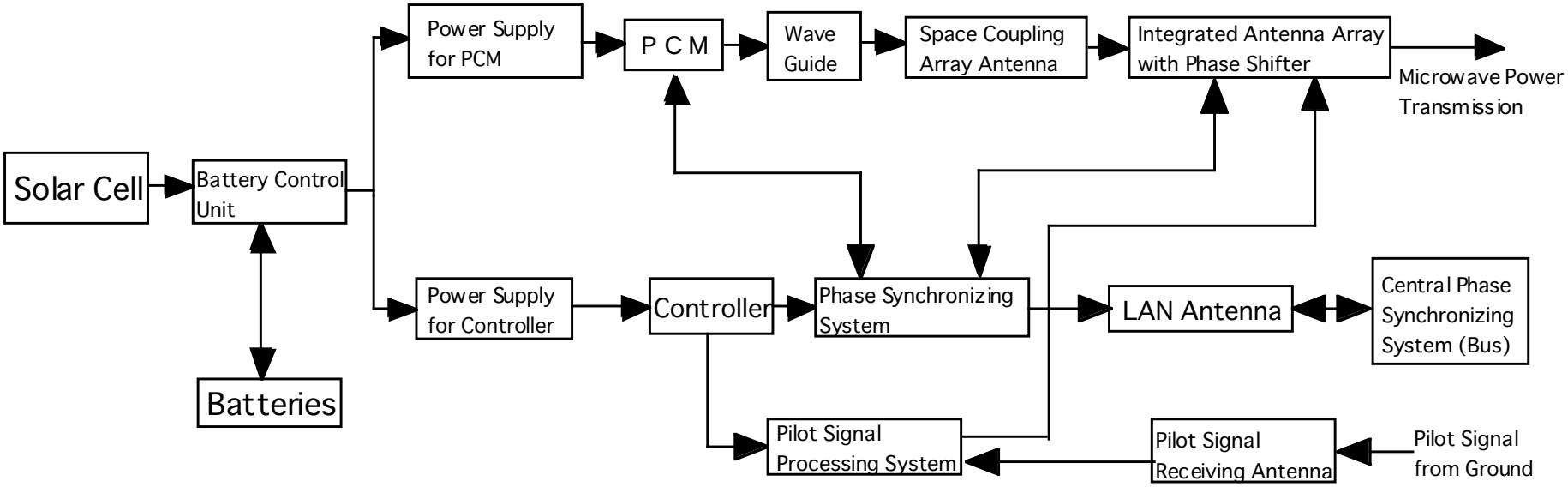


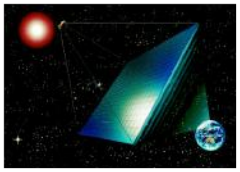
Sequence of Microwave Power Transmission in the Demonstration Experiment





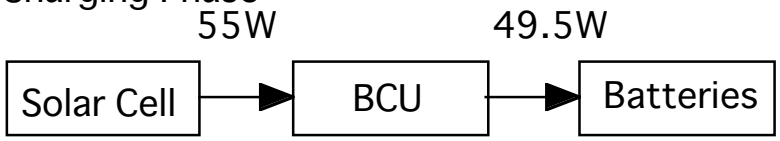
Block Diagram of Module



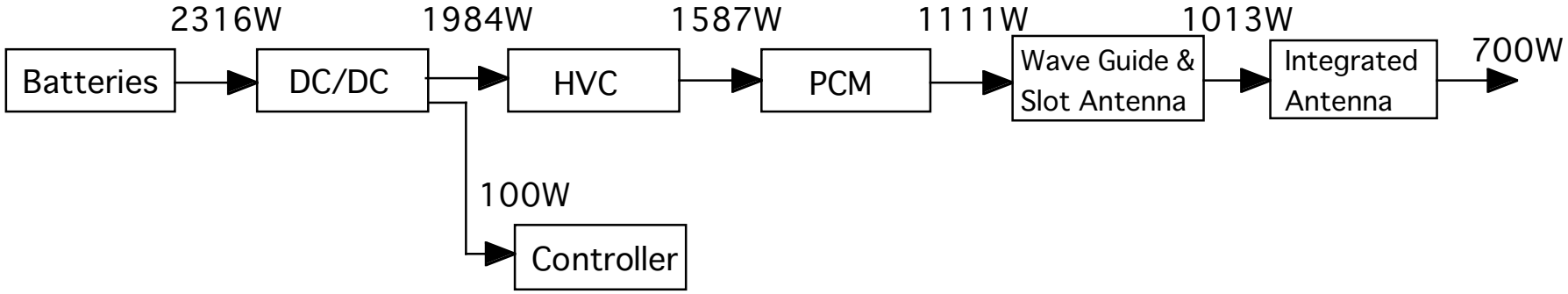


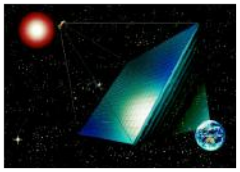
Power Diagram of Module

Charging Phase

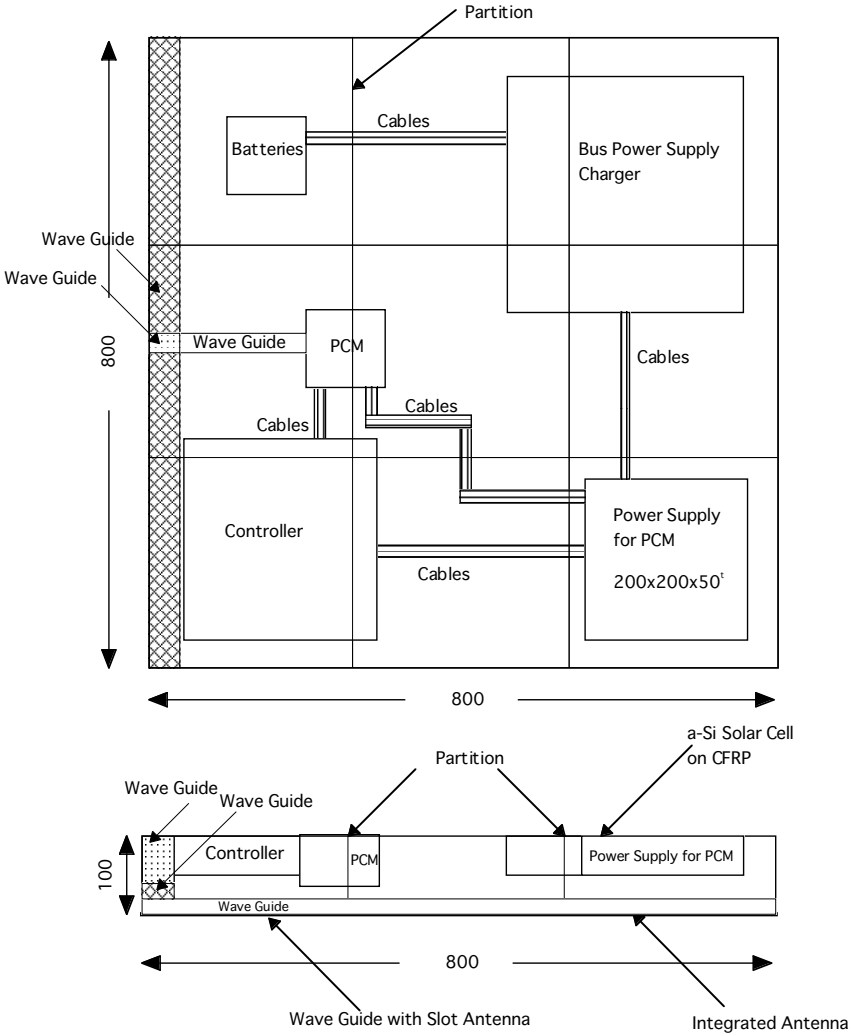


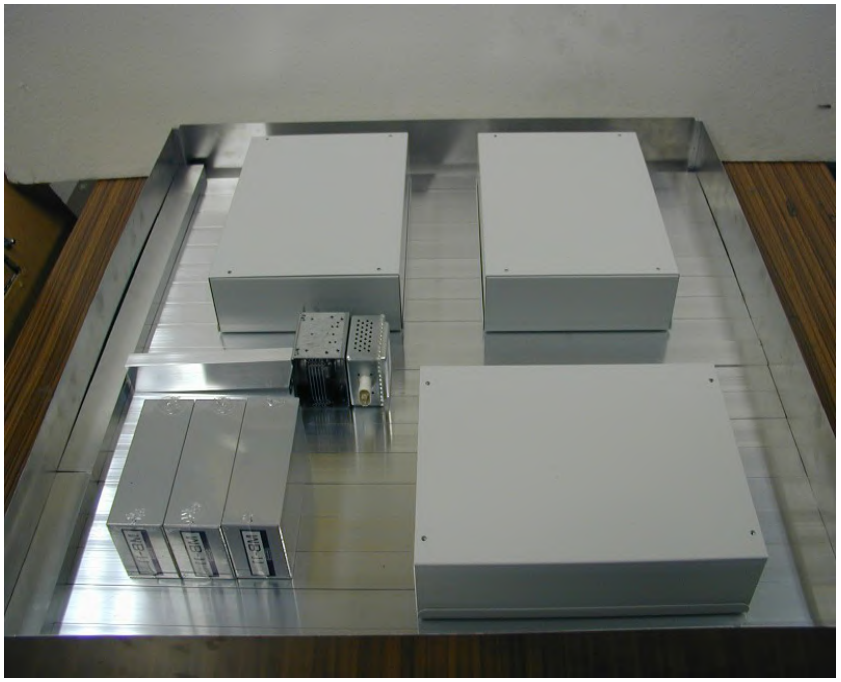
Experiment Phase



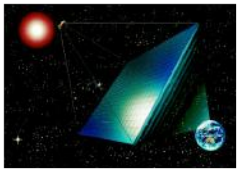


Configuration of Power Generation and Transmission Module





Mock-up of Power Generation and Transmission Module



Summary and Conclusion

- The tethered SPS is a highly practical SPS model, with a number of advantages in the integration, construction, and operation.
- There are two critical technologies for the tethered-SPS; automatic panel deployment and power generation/ transmission module.
- For the automatic deployment of the power generation/transmission panel, an actuator using SMA coils has been investigated and promising results have been obtained.
- The SMA actuator can have the capability for panel deployment, shape control of panel, and dumping of panel oscillation.
- For the power generation/transmission module, the configuration of the components has been designed. The thermal model and functional model will be developed and tested in the next step.