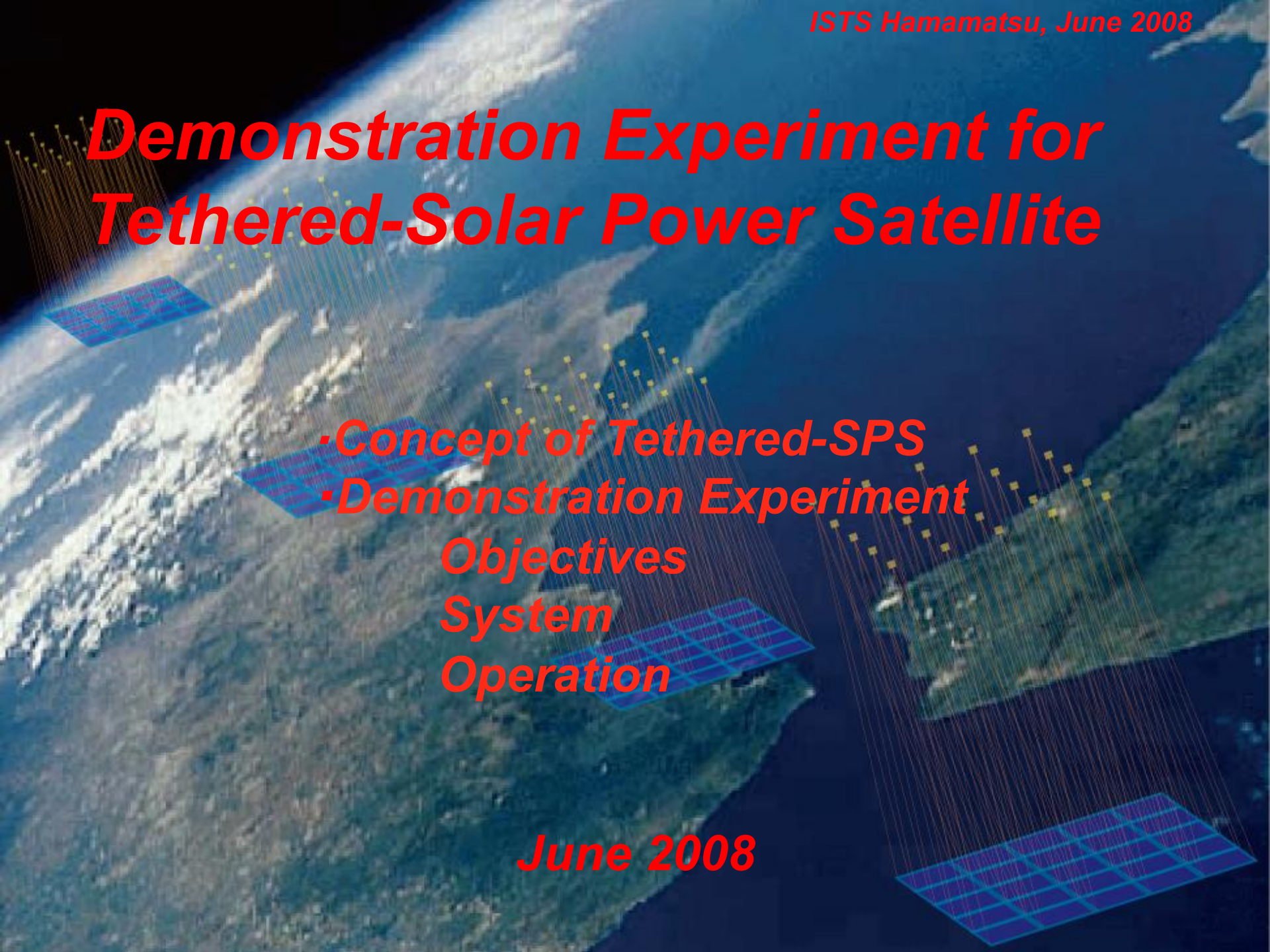
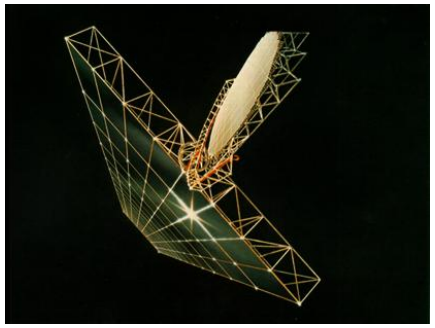
Demonstration Experiment for Tethered-Solar Power Satellite



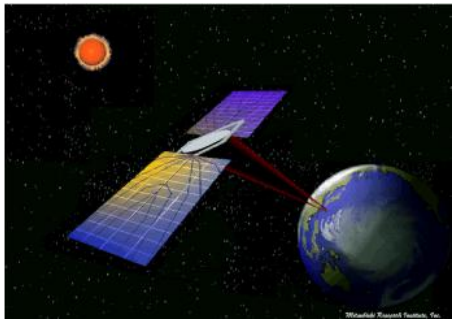
- Concept of Tethered-SPS
- Demonstration Experiment
  - Objectives
  - System
  - Operation

June 2008

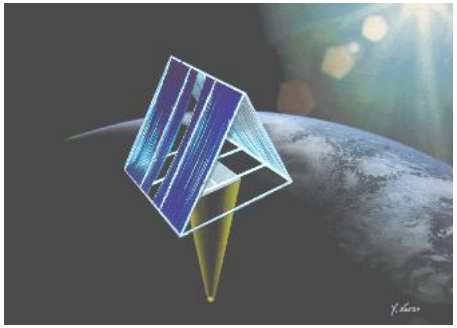
Typical Examples of SPS



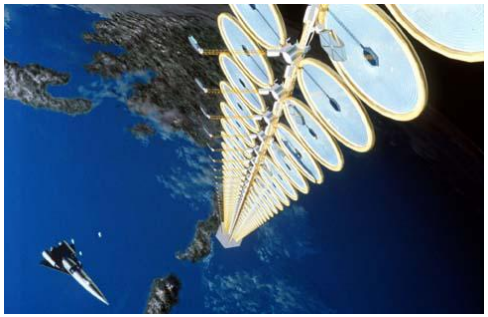
NASA Reference
System 5GW, 1979



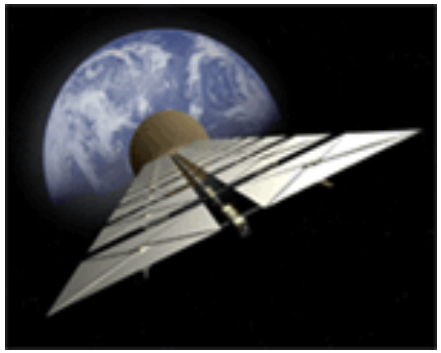
NEDO Grand Design
1GW, 1992



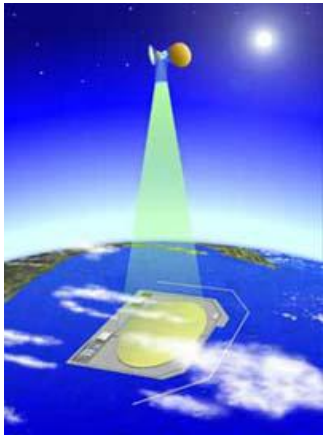
SPS 2000
10MW, 1993



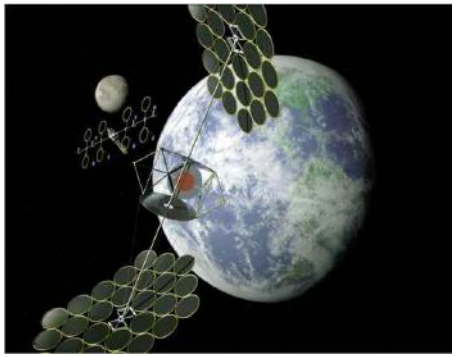
NASA Sun Tower
250MW, 1995



ESA Sail Tower
450MW, 1999



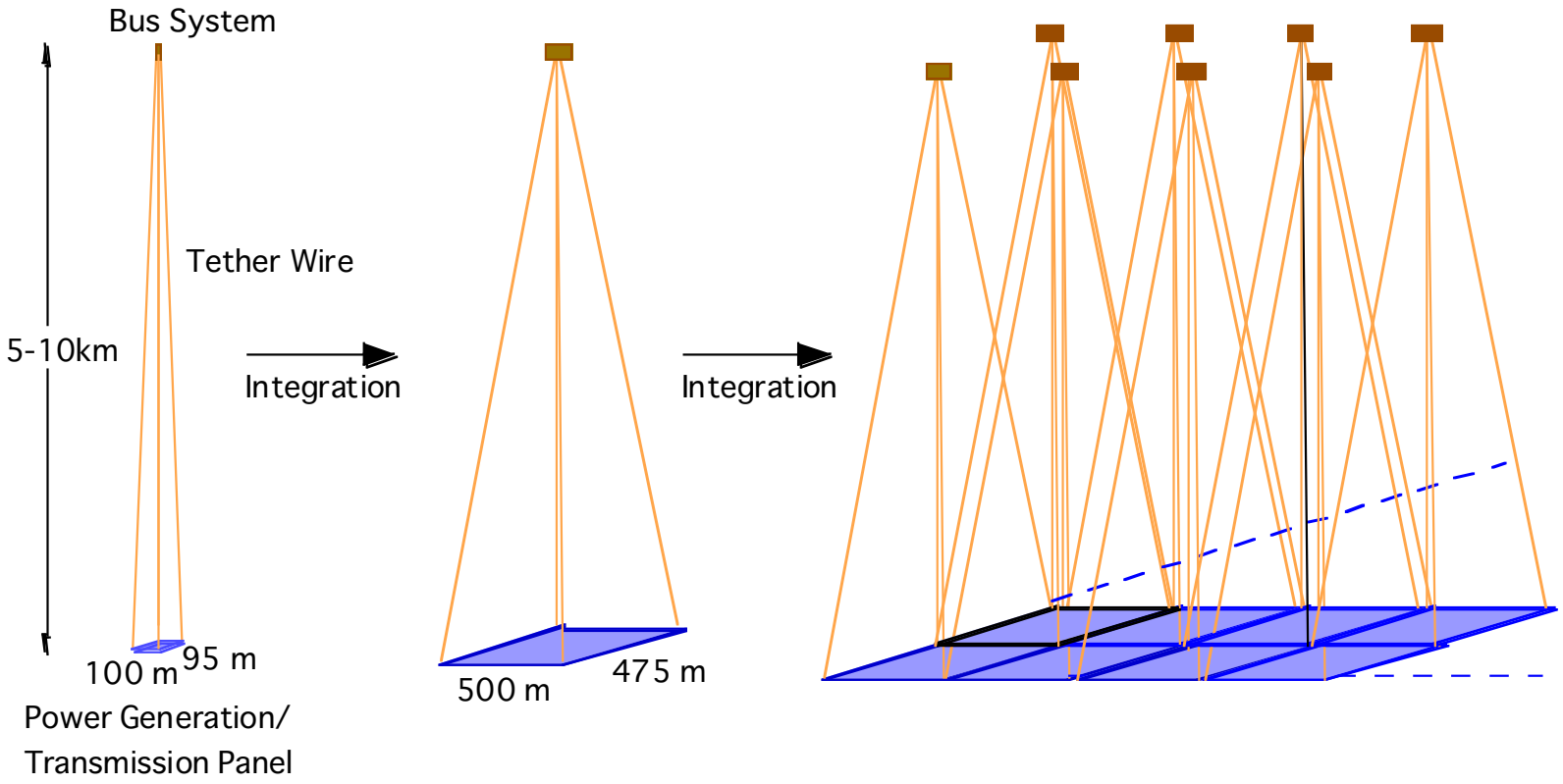
NASDA (JAXA) Model,
1GW, 2001



NASA ISC Model
1GW, 2001

Tethered-SPS
1GW, 2005

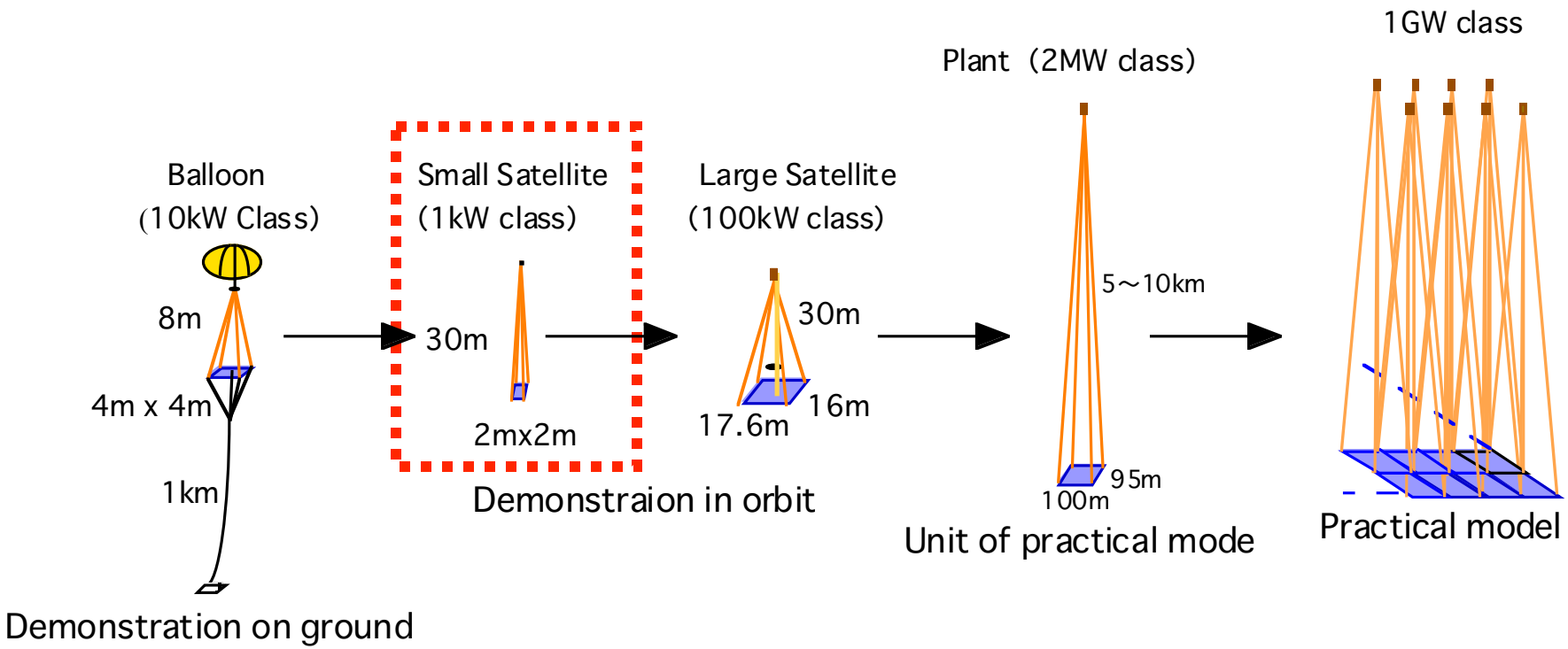
Concept of Tethered-SPS (Separated-bus Type)



System Characteristics of Tethered SPS (Constant Power)

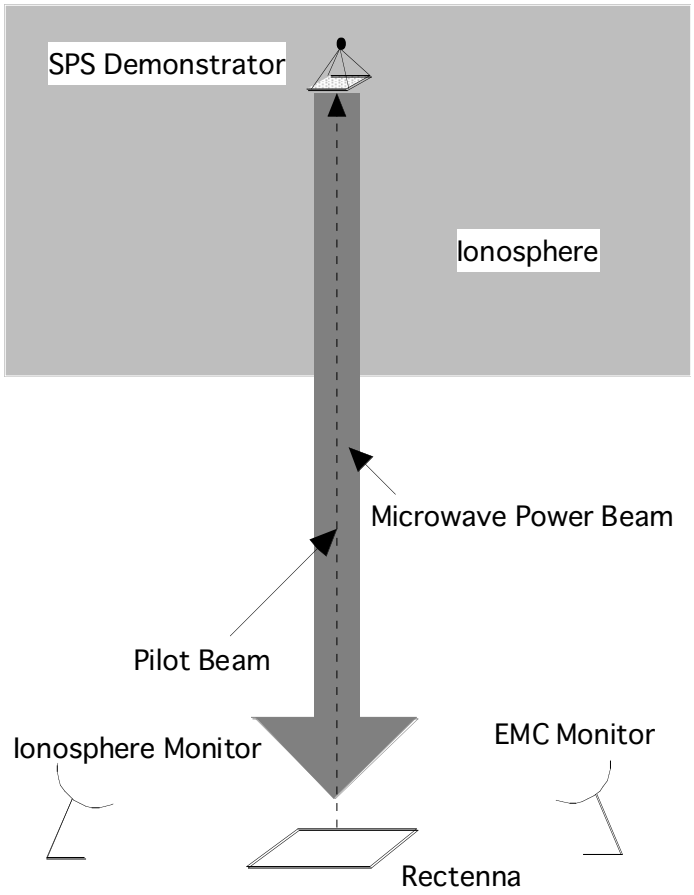
	Item	Performance	Note
Tethered SPS	Weight	26,562 MT	25,234MT（Panel）、1,328MT（Bus）
	Size	2.5 km x 2.375 km x (5-10) km	250 Tethered SPS modules
	Output Power	1.36 GW	Microwave frequency 5.8 GHz
Tethered SPS Module	Weight	42.5 MT	40,375 kg（Panel）、2,125 kg（Bus）
	Tether Length	2-10 km	Width 1cm, Para-aramid fiber （Kevlar/DuPont), UV protection coating
	Panel Size	100m x 95 m	100x 95 Power generation/ Transmission modules
	Output Power	2.2 MW	Microwave frequency 2.45 GHz
Power Generation/ Transmission Module	Weight	4.25 kg	Microwave circuit 2.3kg(10g/W) Solar cell 0.45kg(0.5g/W) Batteriies 1.0kg(2000Wh/kg) Structure 0.5kg(0.025g/cc)
	Size	1 m x 1m x 2 cm	
	Output Power	230 W	Microwave frequency 2.45 GHz

Evolutionary Development from Demonstration Model to Commercial Model



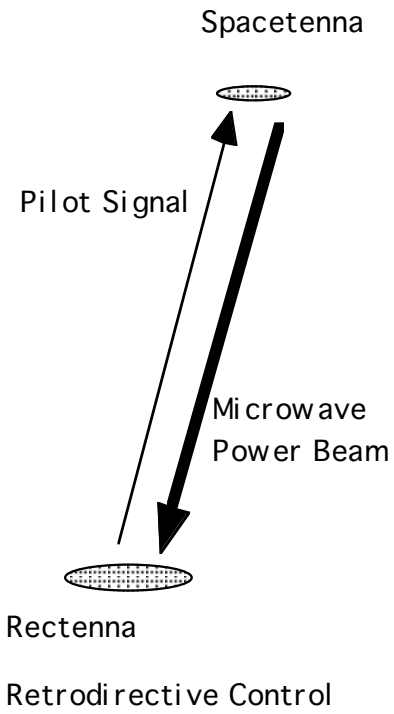
Objectives of Small Satellite SPS

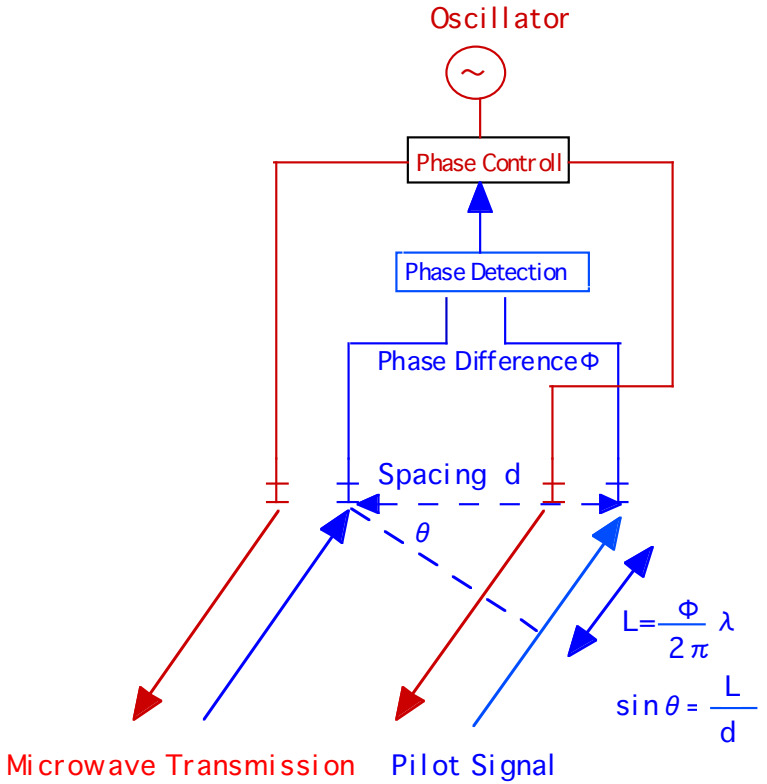
(1) demonstration of the microwave beam control precisely to the target on the ground from the antenna in orbit,
(2) evaluation of the over-all power efficiency as an energy system,
(3) demonstration of the electromagnetic compatibility with the existing communication infrastructure, and ,
(4) study of the operational procedure of the SPS.



On-orbit Verification of Microwave Beam Control

- *Retro-directive beam control to propagate the microwave beam in a long distance through the ionosphere to the rectenna on ground.*
- *Precise beam control under pitch and roll motion of spacecraft.*



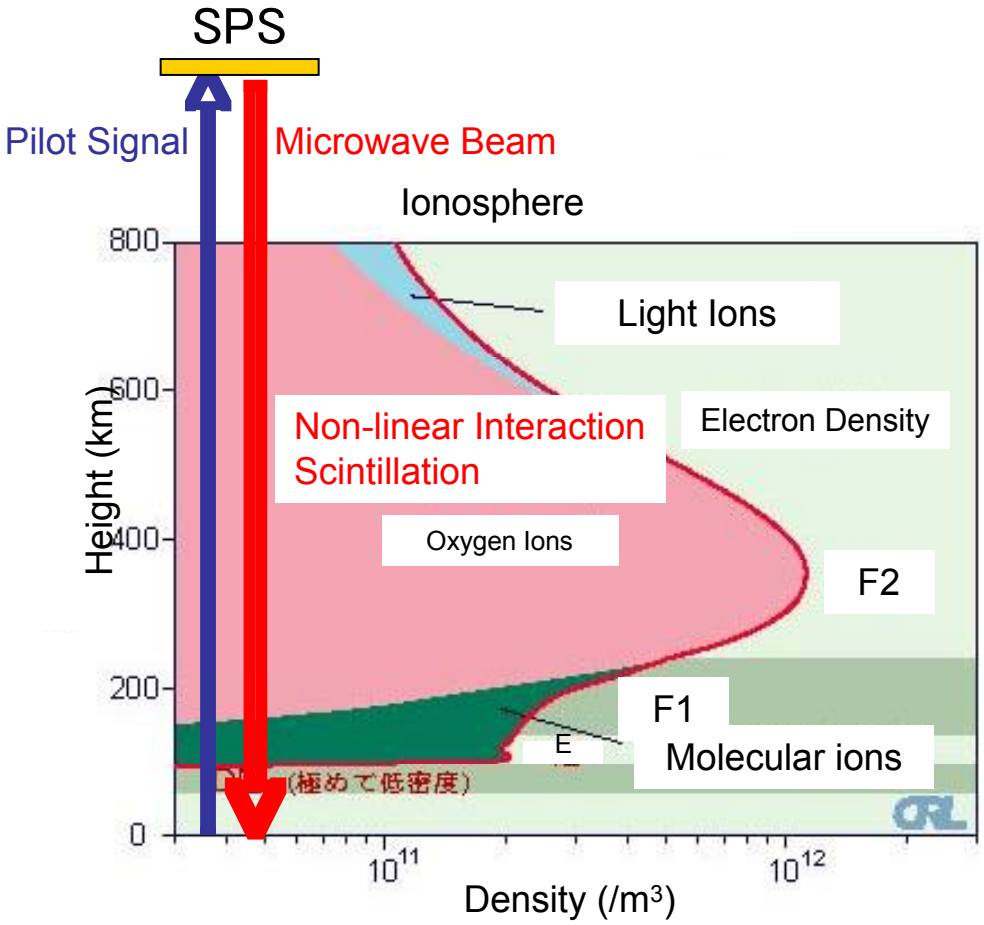


Verification of Microwave Transmission through the Ionosphere

Important Process

1. Phase Disturbance
Stationary : ～10λ (N=5x10^{17} e/m^2)
Scintillation : ～λ (ΔN=5x10^{16} e/m^2)

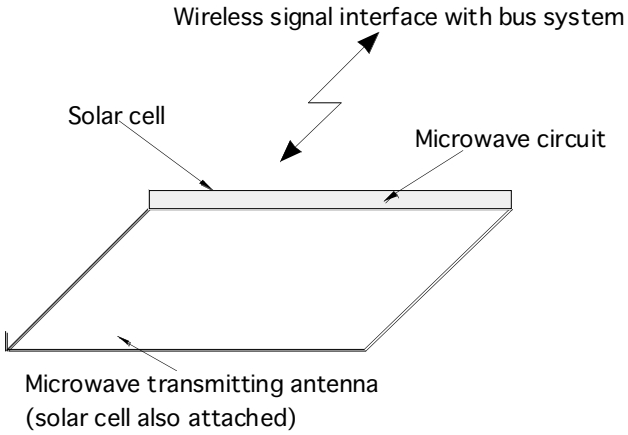
2. Non-linear effects
Self-concentration



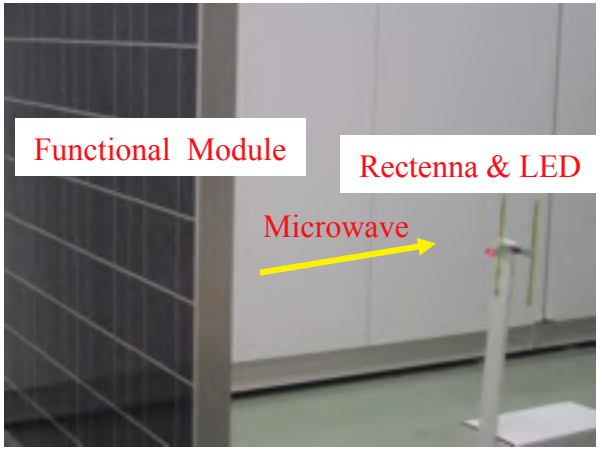
Comparison of System Weight

Phase	Model	Output Powe	Total Weight	Specific Weight	Reference
Commercial	NASA Reference System	6.5 GW	50000 MT	7.7 g/W	
	NASDA 2002 Model	1.34 GW	10000 MT	7.5 g/W	NASDA SSPS Committee Report, 2001
	Tethered-SPS	1.32 GW	27000 MT	20 g/W	
	Sun Tower(GEO)	1.2 GW	15700 MT	13 g/W	Powell et al., 51st IAC, 2000
	Integrated Symmetrical Concentrator	1.2 GW	18000～31500 MT	15g/W～26g/W	Carrington and Feingold, IAC-02-R.P.12
	European Sail Tower	275 MW	2140 MT	7.8 g/W	Seboldt et al., Acta Astronautica, 2001
Demonstration & Experiment	SPS2000	10 MW	240 MT	24 g/W	Conceptual Design Report, 1993
	SPS-WT Experiment Satellite	100kW	8 MT (power generation, transmission)	80g/W	NASDA SSPS Committee Report, 2001
	Tethered-SPS Experiment System for Large satellite	280 kW	18.1 MT	65 g/W	S.Sasaki et al., ISAS Res.Note 2005
	Tethered SPS Experiment System for Small Satellite	0.7kW-2.8kW	65 kg ～ 200 kg	93 g/W ～ 71g/W	

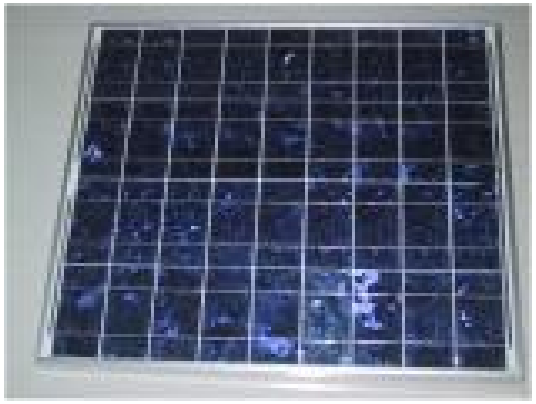
Power Generation/Transmission Module



Power generation/transmission module



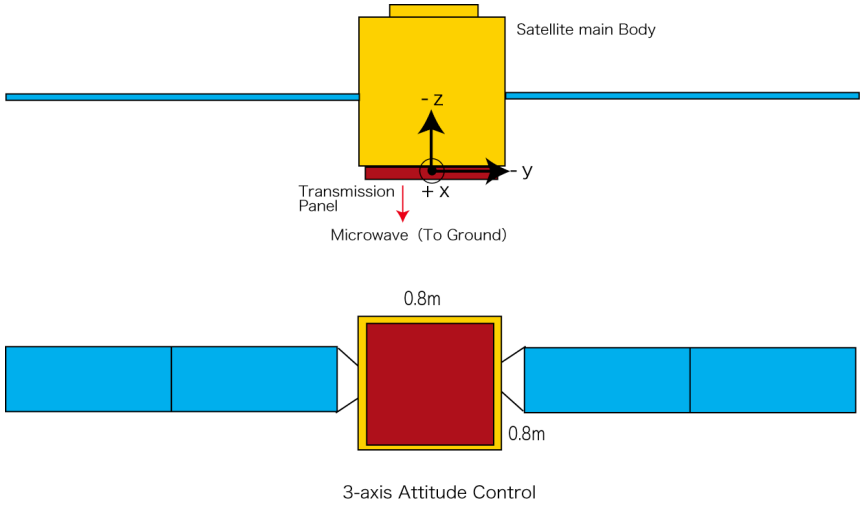
Power Transmission Demonstration



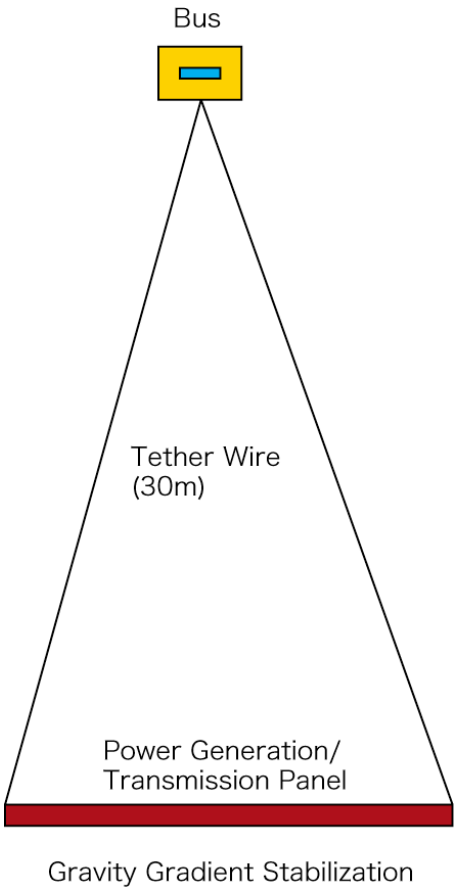
Functional model of module
(solar cell side)

Functional model of module
(microwave antenna side)

Satellite Configuration



Option A（700W, 65 kg）

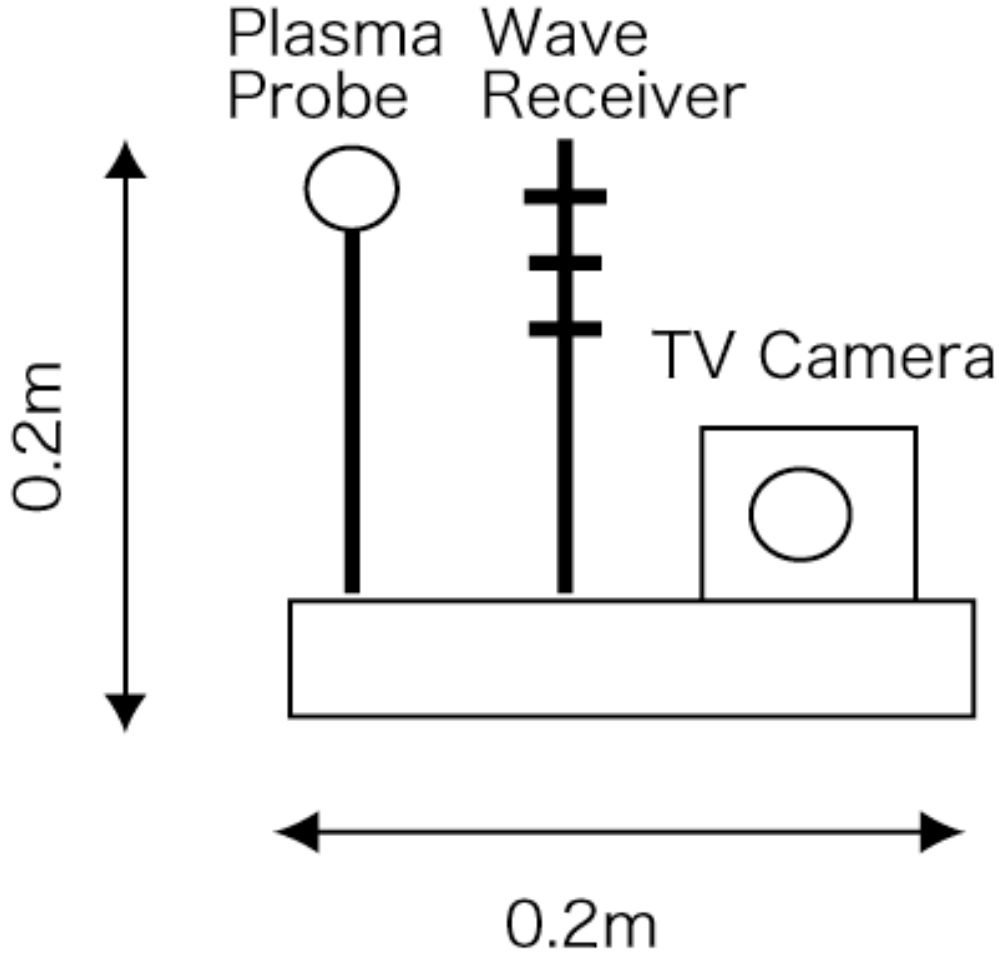


Option B（2800W, 200 kg）

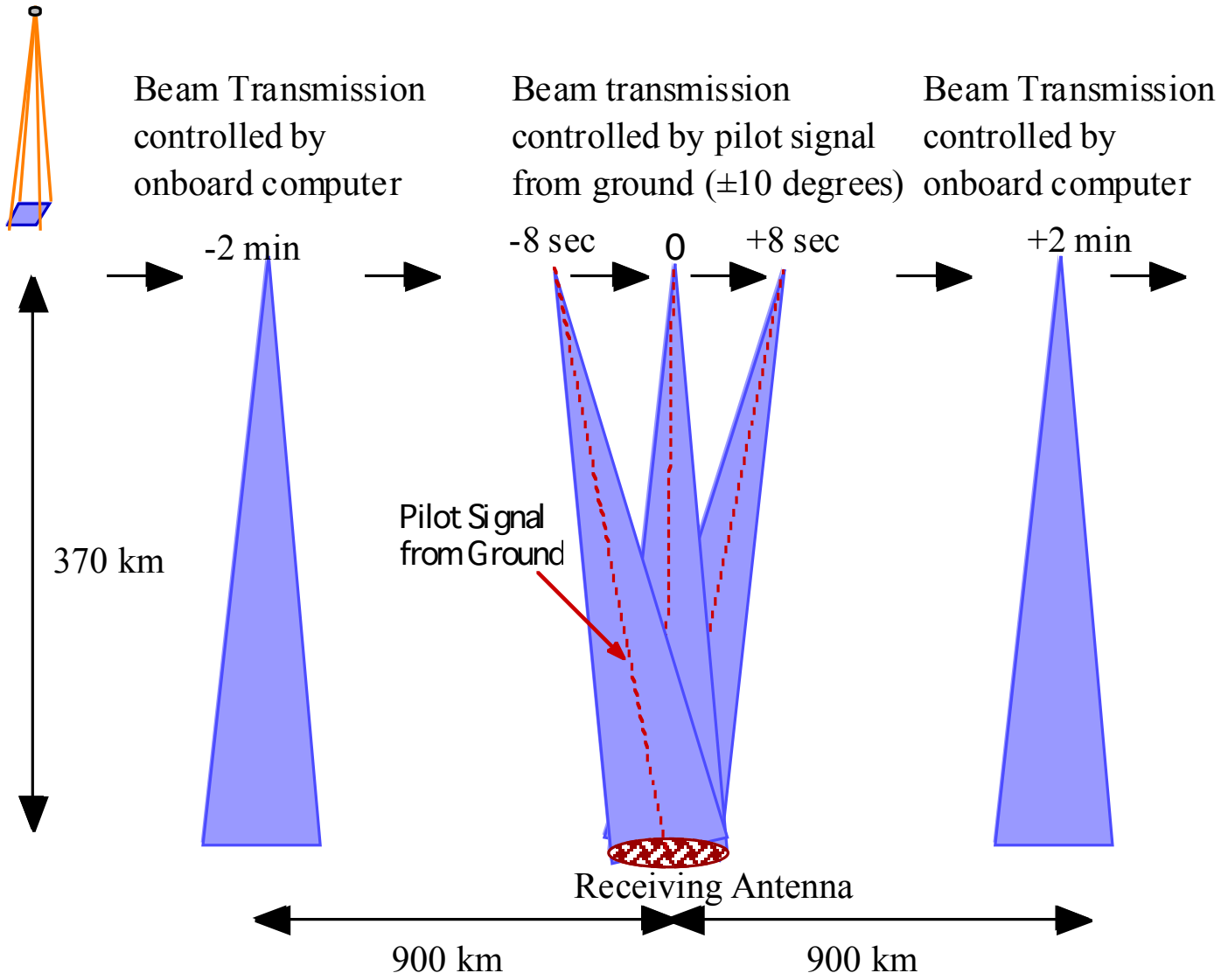
Demonstration Model (Option B)

Mission	Period	1 year
System	Configuration	Power generation/transmission panel suspended by 4 wires
	Panel size	1.6m x 1.6 m x 0.1m
	Tether wire length	30 m
	Total weight	200 kg
	Attitude stability	±1°
Power generation	Thin film solar cell array	350 W (85 W/module)
Power transmission	Frequency	5.8 GHz
	Phase control	5 bit
	Number of module	4
	Beam control	Retro-directive/Computer control, ±10°
	Output power	700W/module, 2.8kW(total)
	Power density	1,100W/m^2 (antenna) 1.4μW/m^2(ground)
Ground stations		JAXA ground stations International experiment sites

Plasma Diagnostic Package (Option A, B)



Experiment Sequence (Option B)



Summary and Conclusion

- *A microwave transmission experiment, kWatt class, on small satellite is proposed based on the current SPS technologies.*

- *It will demonstrate the retro-directive technology for microwave beam transmission in a long distance and will verify the high-density microwave propagation through the ionosphere.*

- *This will be the first SPS demonstration experiment in orbit that will greatly attract public attention and promote SPS research .*

- *Further investigations are required to confirm the technical feasibilities, especially for microwave control system.*