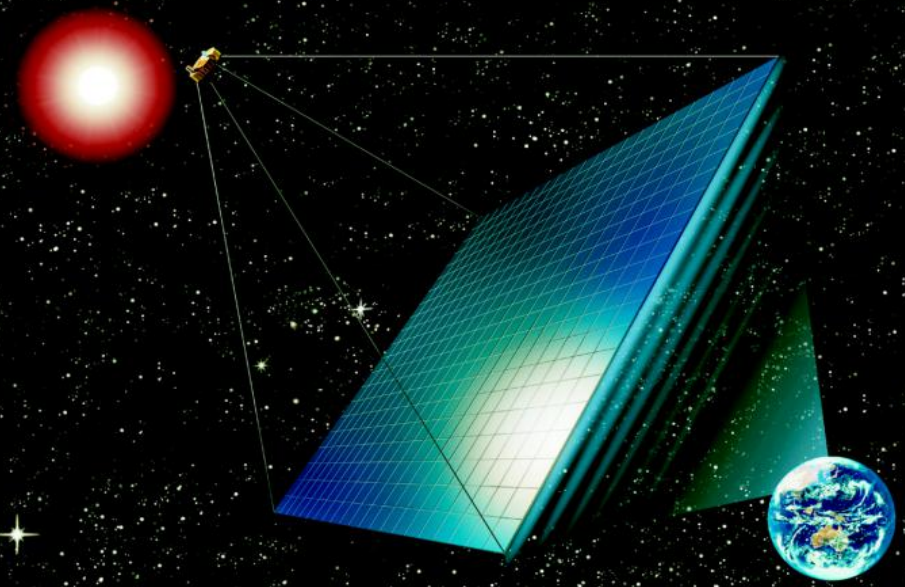
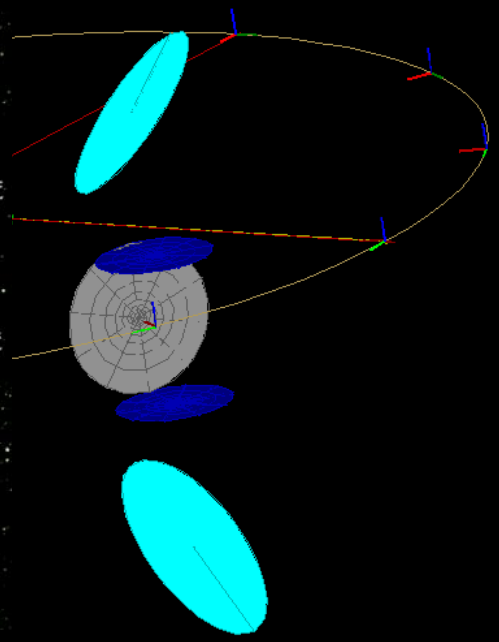
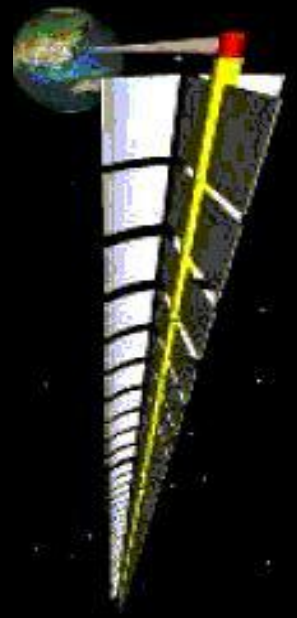
SPS Concepts and Activities at the Japan Aerospace Exploration Agency

- Commercial SPS Models Currently Studied in Japan
- Roadmap towards Commercial SPS
- 1 kW Class Wireless Power Transmission Experiment on Ground
- 1 kW Class Microwave Power Transmission Experiment in Space

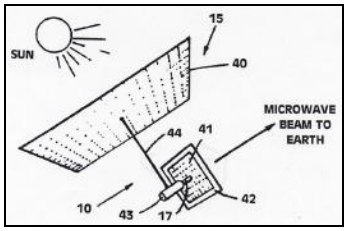






June 2010

Typical SPS Models

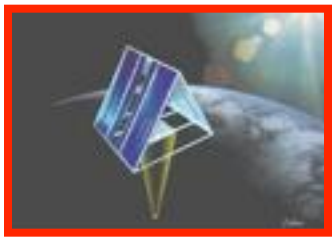


Solar Power Satellite

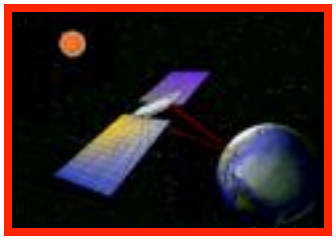
Non-concentrator

Bus Power

NASA Reference Model

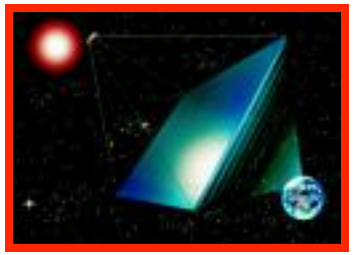


SPS2000



NEDO Grand Design

Distributed Power

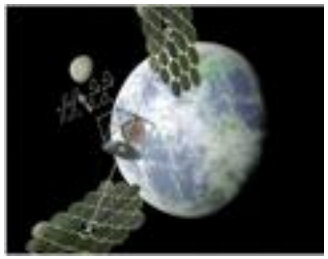


USEF Tether SSPS

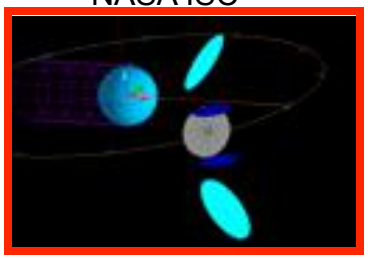
Concentrator

Bus Power

NASA Sun Tower



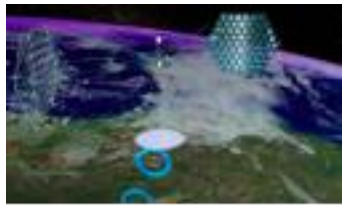
NASA ISC



JAXA M-SSPS

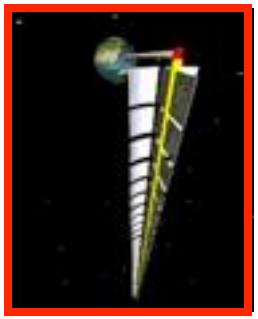
Distributed Power

NASDA 2001



IAA Study Model

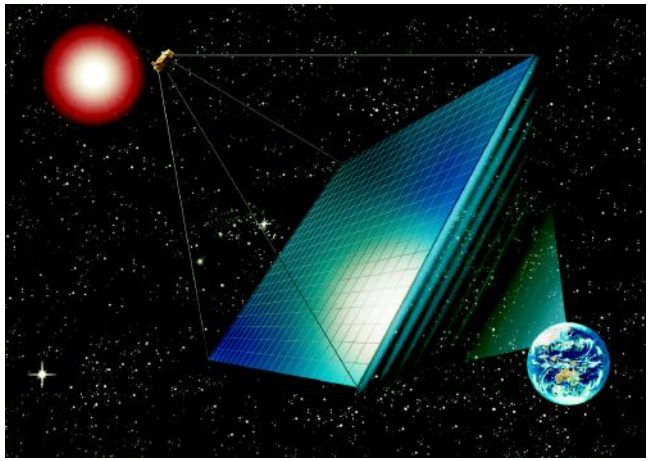
Laser Direct Excitation



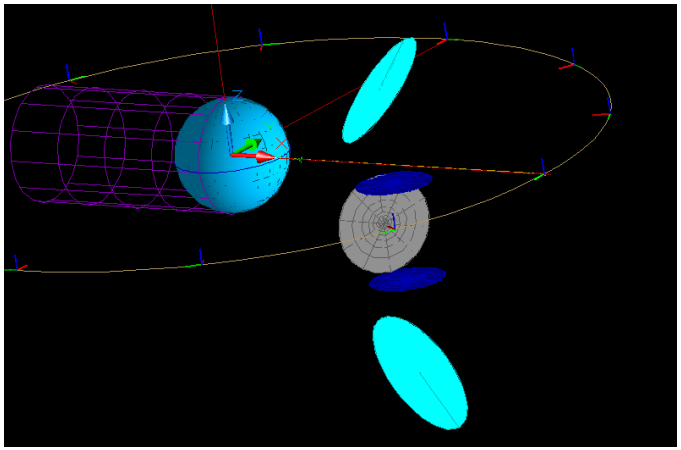
JAXA L-SSPS

Designed in Japan

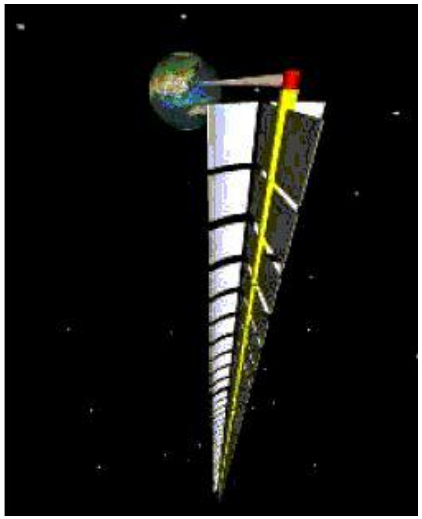
Commercial SPS Models Currently Studied in Japan



Basic Microwave-type Model (USEF/METI)



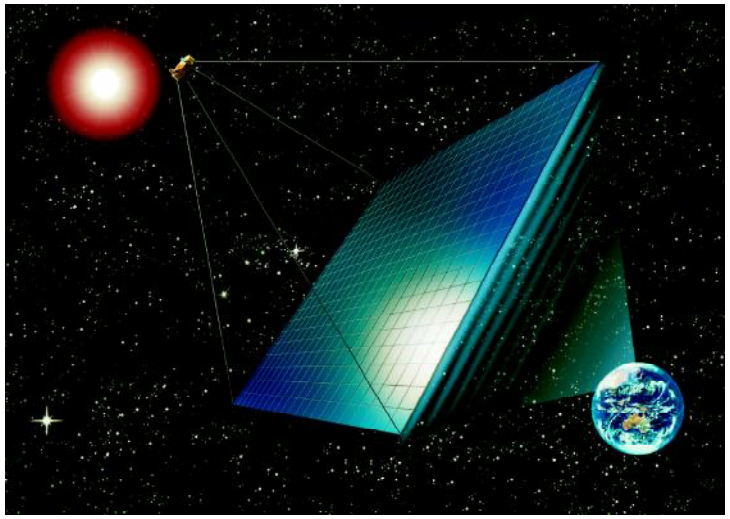
Advanced Microwave-type Model (JAXA/MEXT)



Laser Model (JAXA/MEXT)

USEF/METI:Unmanned Space Experiment Free Flyer/ Ministry of Economy, Trade and Industry
JAXA/MEXT:Japan Aerospace Exploration Agency/ Ministry of Education, Culture, Sports, Science and Technology

Microwave-type SPS (Basic Type, Tethered-SPS)



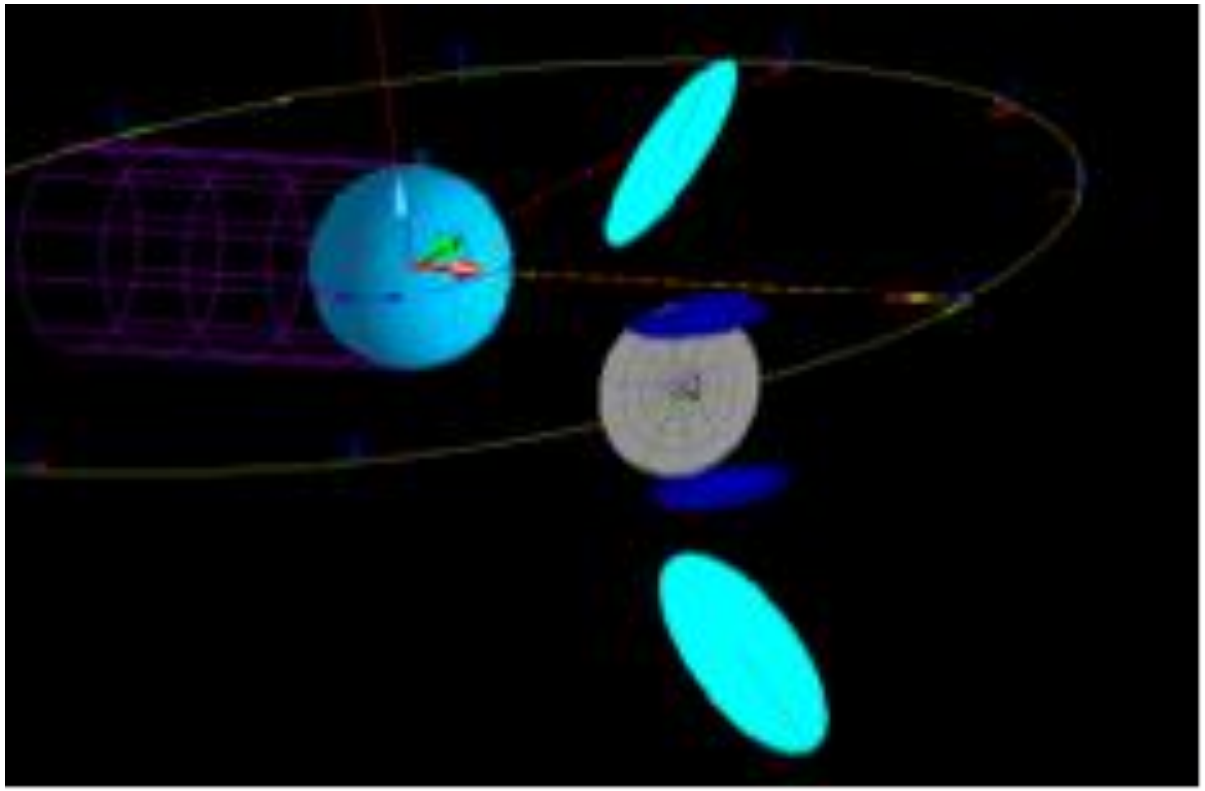
Single-Bus Model

Earth pointing 1 GW-SPS
Power generation/transmission panel 2km x 1.9km x(2-10)cm^t
Suspended by tether wires of 5-10 km
Unit panel 100m x 100m size
Total weight 20,000 tons

Multi-Bus Model

Simple but low rate power collection (64%)

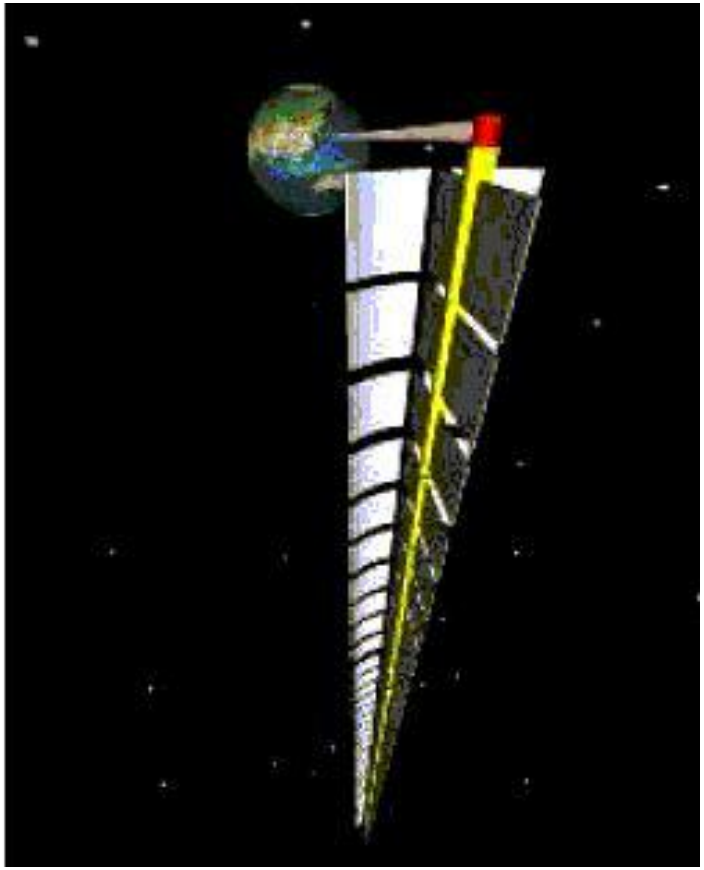
Microwave-type SPS (Advanced Type)



Sun pointing 1GW-SPS
Reflection mirrors (free flying) : 2.5 km x 3.5 km

1000 tons x 2sets、100~300g/m²
Power generation: 1.25 kmΦx2 sets
Power transmission: 1.
8 km Φ
Total weight: 10,000 tons(target)
Complicated but high rate power collection

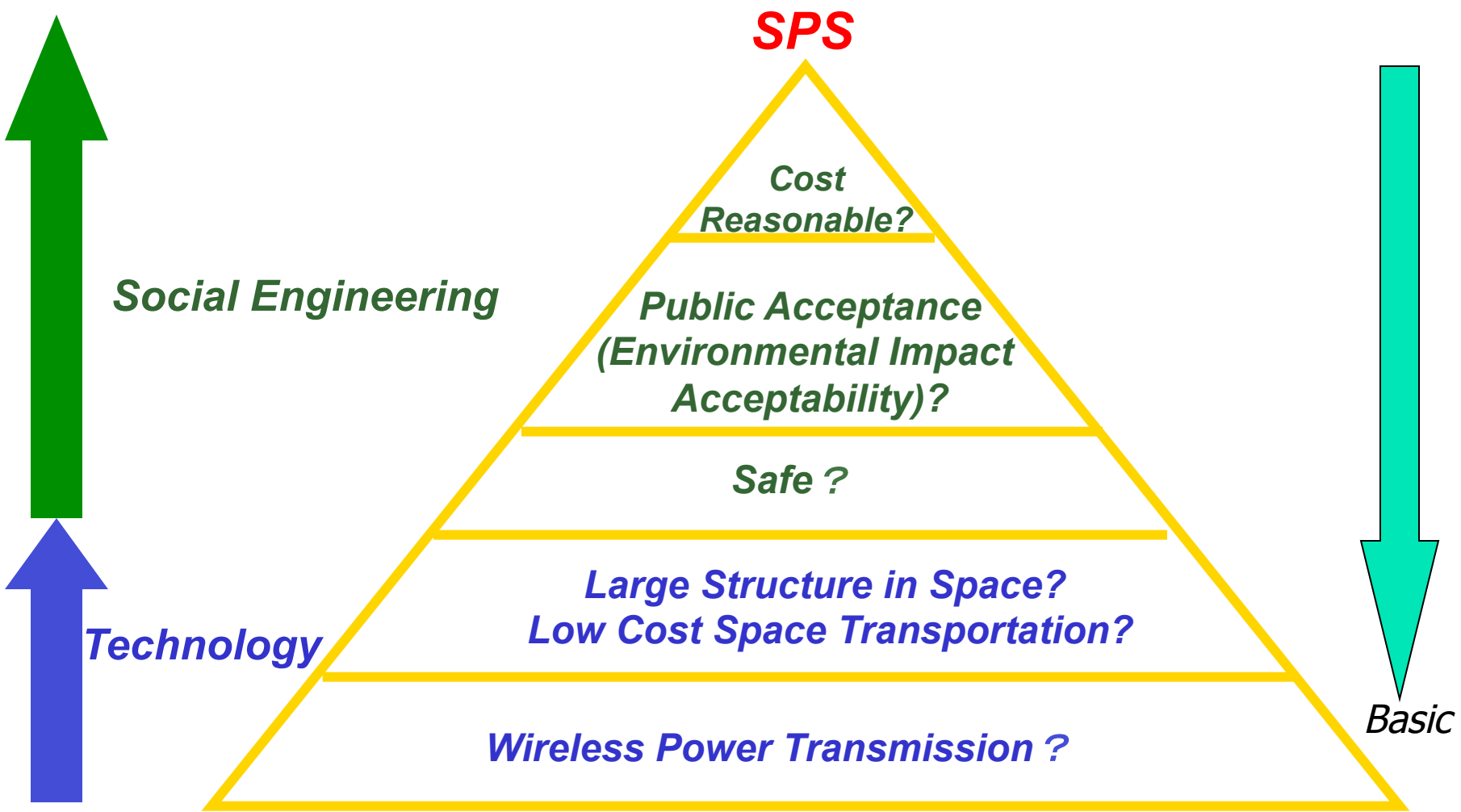
Laser-type SPS



1GW Model, 10MW Module x 100
Reflective mirrors: 100m x 100 m x2
Radiator: 100 m x 100 m
Laser excitation directly from the sunlight
Nd:YAG crystal(Cr doped)
Light concentration 500-1000 times
Total weight:5000 tons(target)
Beam diameter:400m
Small Scale, but technologies prematured

Questions to be Answered towards SPS

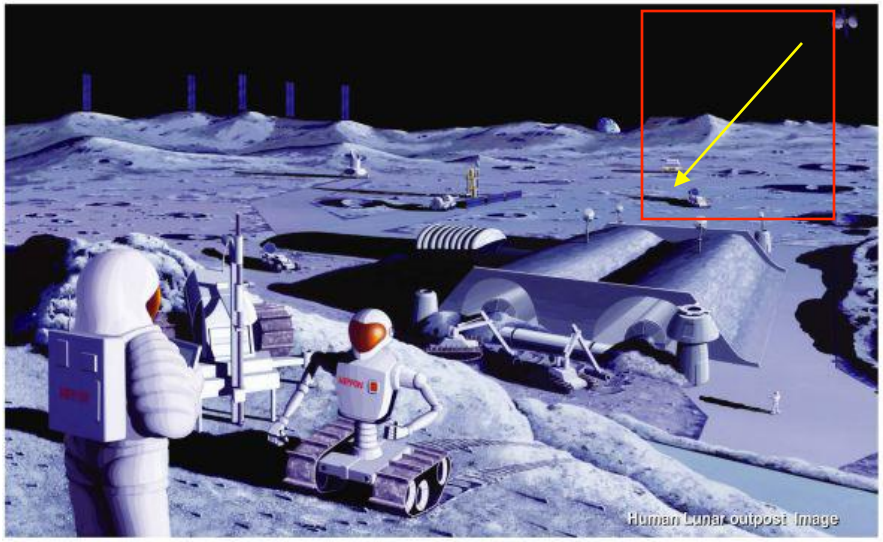
All questions should be answered with "YES" eventually.
Upper level question can be answered only when the lower level question is answered with "YES".
We have to start with the most basic (lowest level) question to answer "YES".



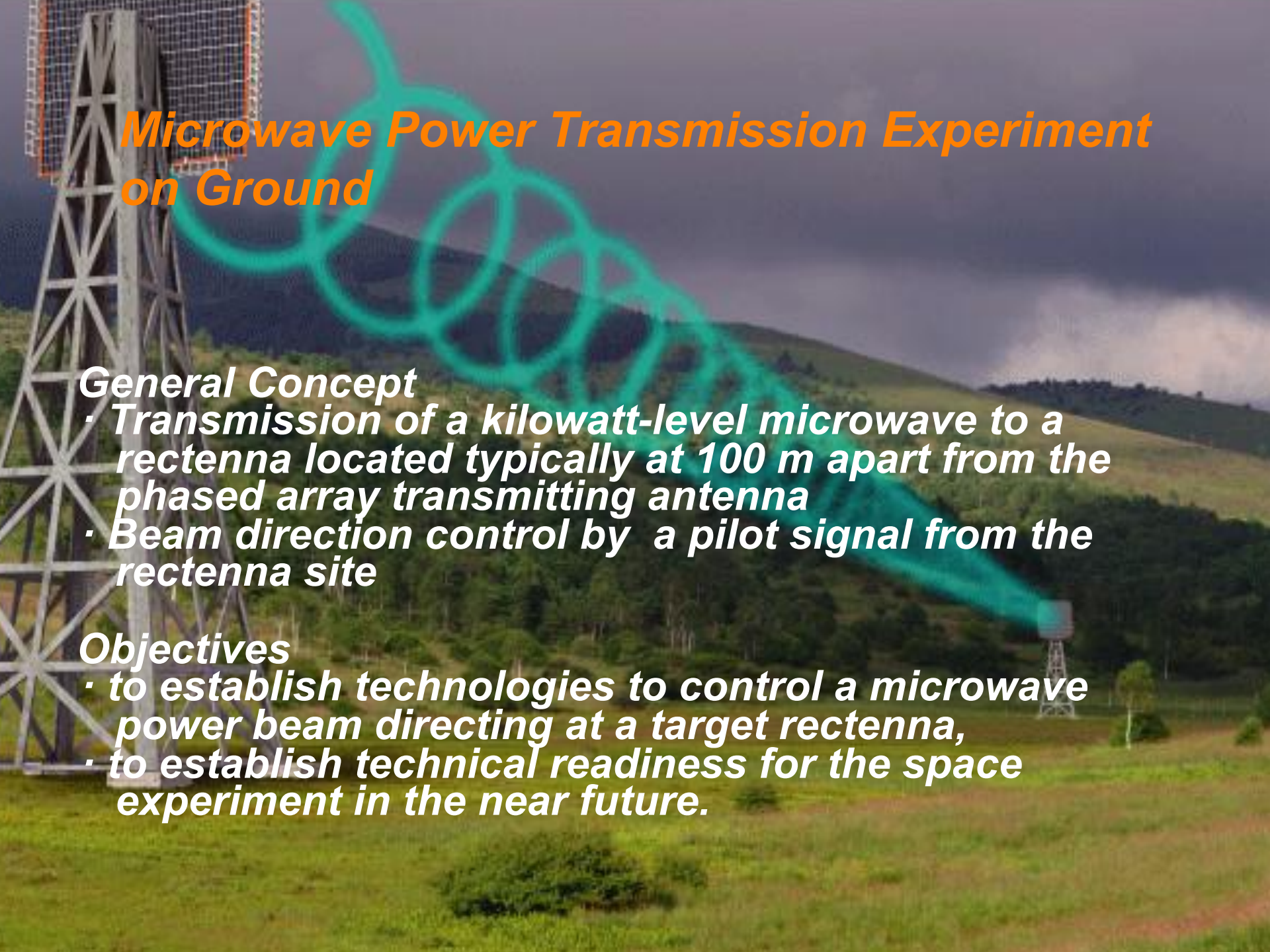
Laser Power Transmission for Lunar Exploration

Shackleton crater, a potential candidate for water ice

Power transmission to a rover in the shadow inside the crater



Power transmission from lunar orbit to lunar base

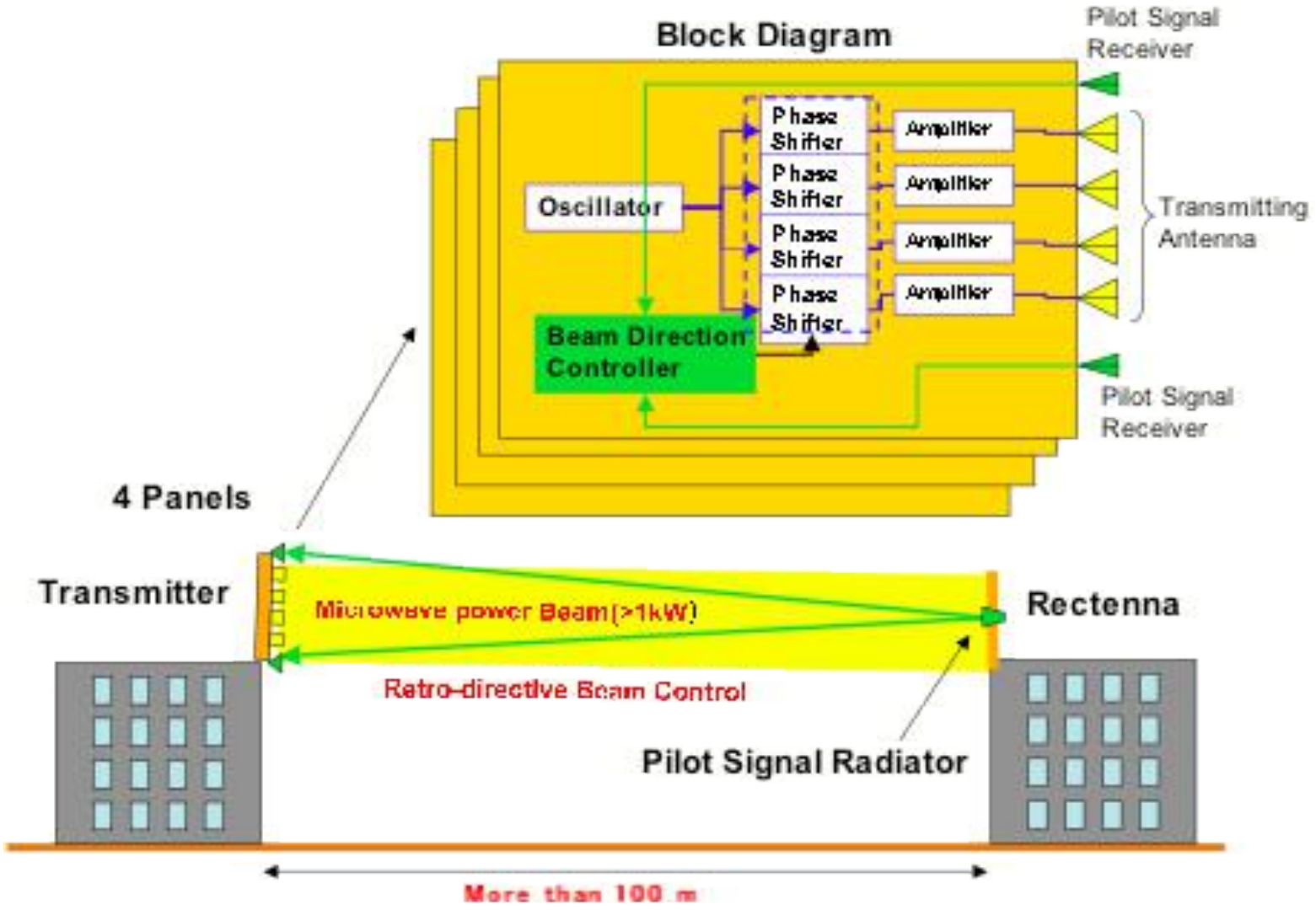


Microwave Power Transmission Experiment on Ground

General Concept
- Transmission of a kilowatt-level microwave to a rectenna located typically at 100 m apart from the phased array transmitting antenna
- Beam direction control by a pilot signal from the rectenna site

Objectives
- to establish technologies to control a microwave power beam directing at a target rectenna,
- to establish technical readiness for the space experiment in the near future.

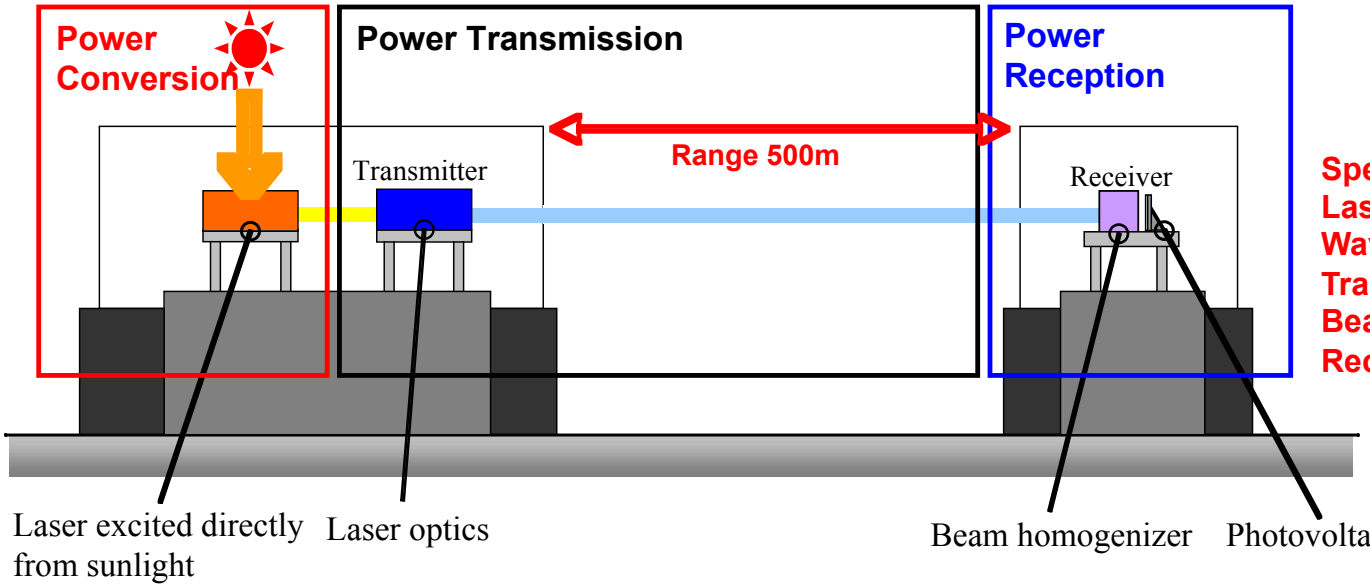
Configuration of Microwave Power Transmission Experiment



Characteristics of Microwave Transmission Experiment on Ground

Transmitter configuration	4 panels movable to each other. 700W/panel, 30 kg/panel (typical),
Microwave transmission panel	169 sub-array/panel, 4 antennas/sub-array, 80 cm x 80 cm, 2cm thick microwave conversion efficiency >40 %
Microwave amplifier	5.8 GHz, 4.5 W, efficiency >50 %
Antenna configuration	0.65 λ spacing
Microwave beam control	Retro-directive control using a pilot signal from rectenna site
Phase control accuracy	5 bits
Rectenna configuration	2.5 m x 2.5m, 72 modules DC conversion efficiency >70%
Transmission range	100 m (typical)

Laser-SPS Demonstration Experiment on Ground(1kW class)



Specification
Laser output 1kW
Wave length 1.06μm
Transmission 500m
Beam control several μrad
Receiver output 0.2kW

Laser Power Transmission experiment(200W class) at Kakuta/JAXA

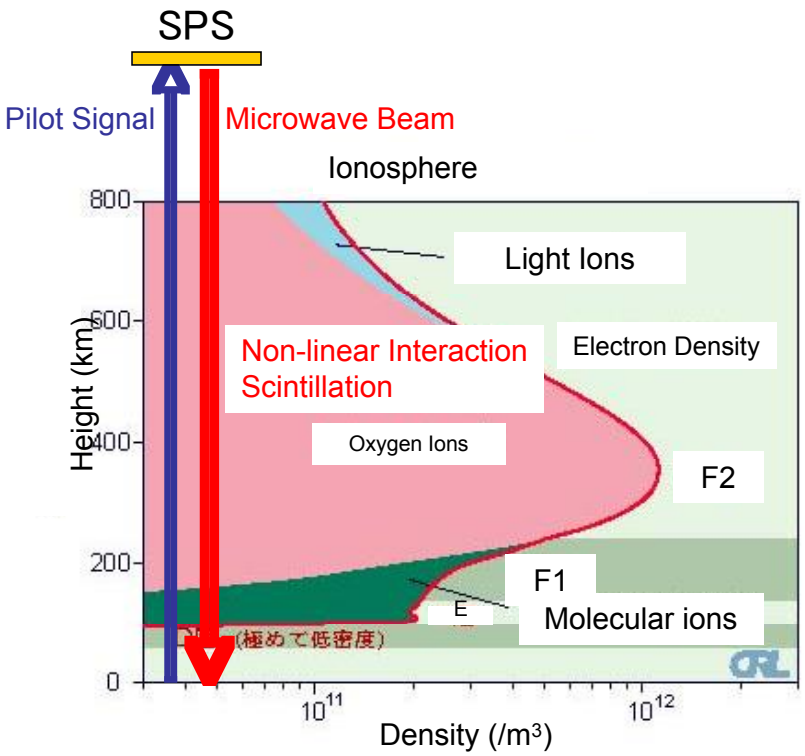
Microwave Transmission Experiment in Space

(1) demonstration of the microwave beam control precisely to the target on the ground from the antenna in orbit,

(2) verification of microwave power transmission (~kw/m^2) through the ionosphere,

(3) evaluation of the over-all power efficiency as an energy system,

(4) demonstration of the electromagnetic compatibility with the existing communication infrastructure.



System Characteristics of Demonstration Model

Mission	Period	1 year
System	Configuration	Power generation/transmission panel suspended by 4 wires
	Panel size	1.6m x 1.6 m x 0.02m
	Tether wire length	30 - 100 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	950W/module, 3.8kW(total)
	Power density	1500,1000, 500, 100W/m^2 (at antenna) 1.9μW/m^2(max, on ground)
Ground stations		JAXA ground stations International experiment sites

100 kW class 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)*

Verification Matrix towards Commercial SPS

Phase / Verification	Ground Demonstration	Small Satellite or JEM on Space Station	Large Satellite	Small Plant	Verification Plant
	kW Ground	kW Low Earth Orbit	100kW Low Earth Orbit	2MW 1000 km Altitude	200 MW Geostationary Orbit
Beam Control	100m	400km	400km	1000km	36000km
Ionosphere/ atmosphere transmission	-	1kW/m^2	1kW/m^2	1kW/m^2	1kW/m^2
Power Transmission	(Test Rectenna kW)	-	Small Rectenna 10kW	Large Rectenna 2MW	Large Rectenna 200MW
SPS Total Function	-	-	10kW	2MW	200MW
Power for Practical Use	-	-	-	2MW	200MW

Summary and Conclusion

- Three commercial SPS models currently studied in Japan; basic microwave-type, advanced microwave-type, and laser type, are introduced.
- As the first demonstration on the ground towards the commercial models, kW-class wireless power transmission experiments with100-500 m range is now under development and will be completed within three years, both for microwave and laser.
- Immediately after the ground demonstration experiment, we will start a small-scale experiment in orbit to transmit a 1 kW class microwave power to the ground.
- After an assessment of the results from the ground and space experiments, we propose to start a larger-scale experiment of 100 kW class in orbit.
- This approach is in accordance with the basic plan on space development by the government's space development strategy headquarter in Japan.