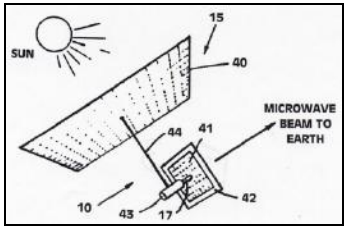
SSPS Development Roadmap

- Commercial SSPS Currently Studied in Japan
- Roadmap towards Commercial SSPS
- 1 kW Class WPT Demonstration on the Ground
- 1 kW Class WPT Demonstration in space
- 100 kW class SSPS demonstration in space
- and then…

Oct. 2009

SSPS Classification

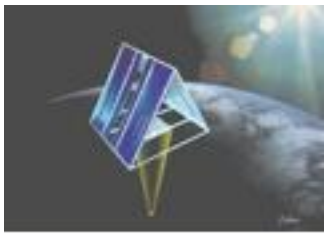


Solar Power Satellite

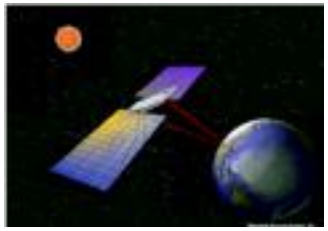
Non-concentrator

Bus Power

NASA Reference Model

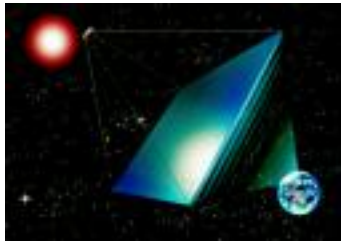


SPS2000



NEDO Grand Design

Separated Power

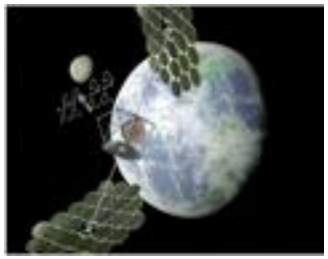


USEF Tether SSPS

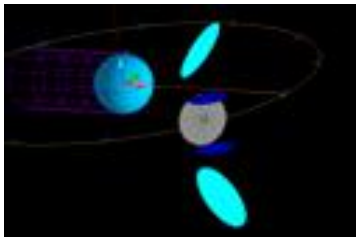
Concentrator

Bus Power

NASA Sun Tower



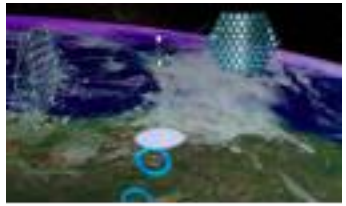
NASA ISC



JAXA M-SSPS

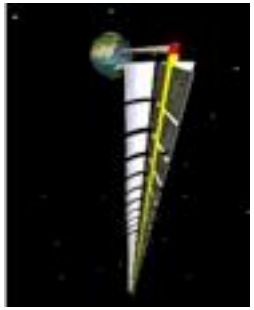
Separated Power

NASDA 2001



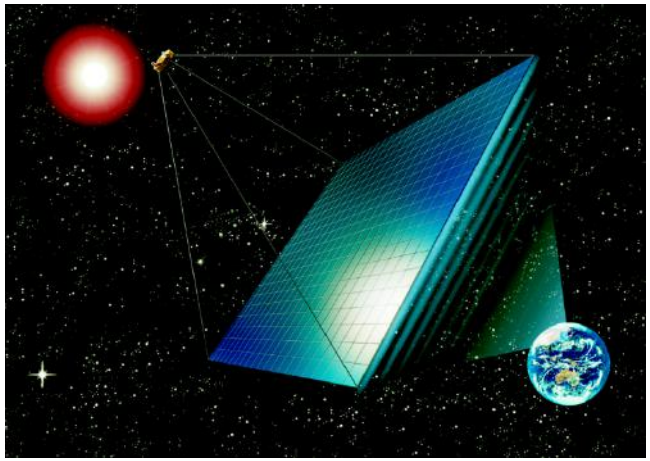
IAA Study Model

Laser Direct Excitation

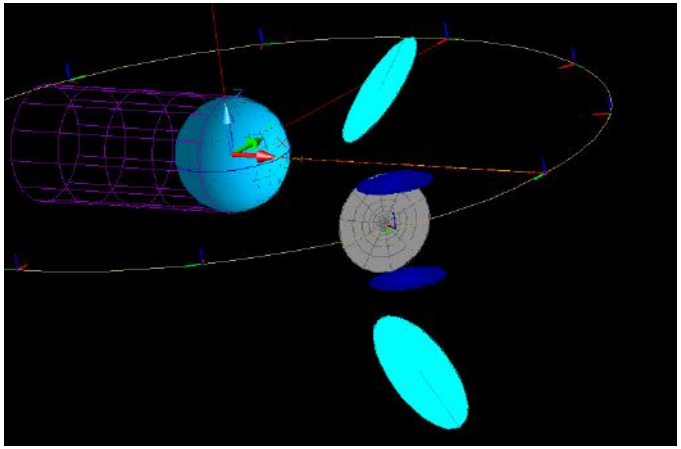


JAXA L-SSPS

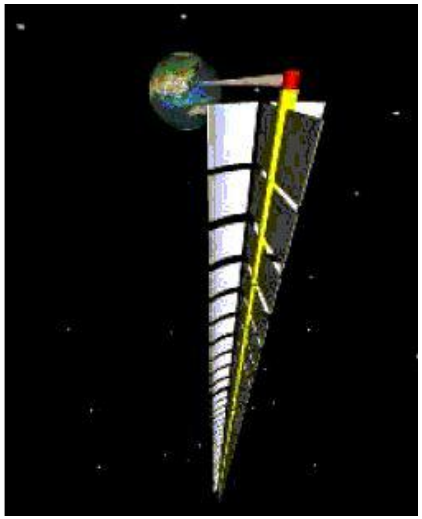
Commercial SSPS Currently Studied in Japan



Basic Microwave-type Model (USEF/METI)

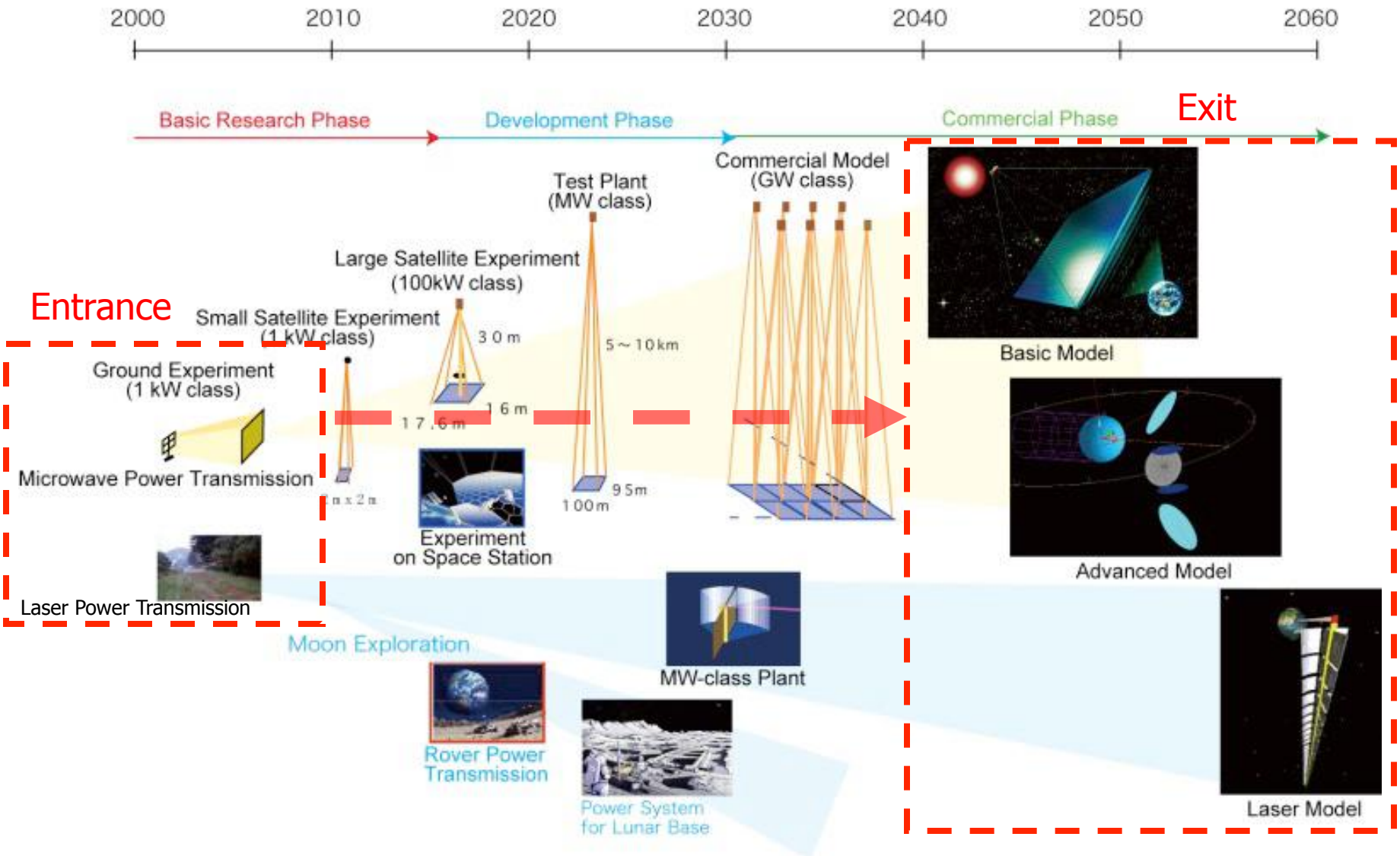


Advanced Microwave-type Model (JAXA)



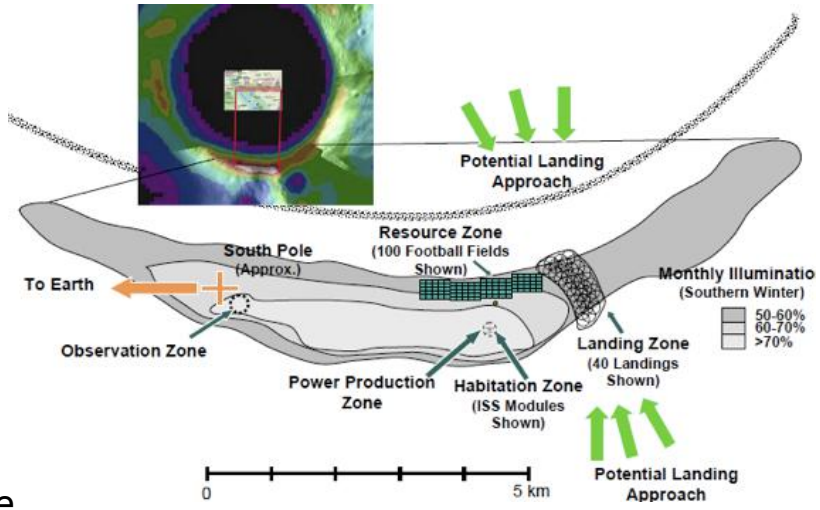
Laser Model (JAXA)

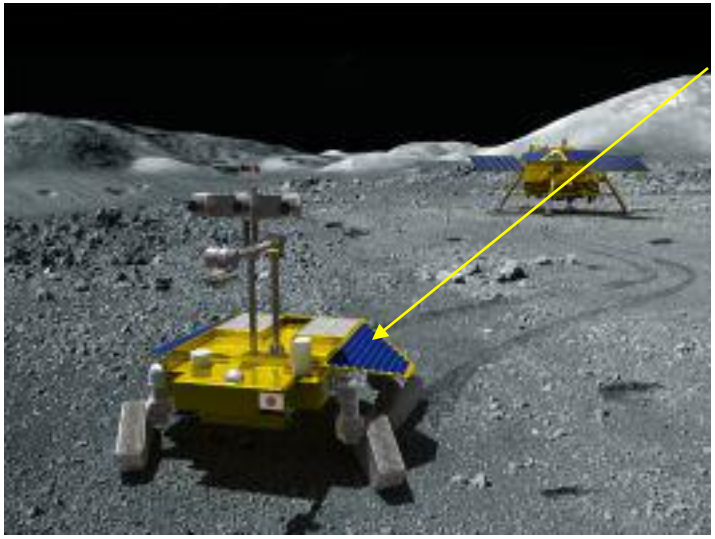
Japanese Roadmap for SSPS



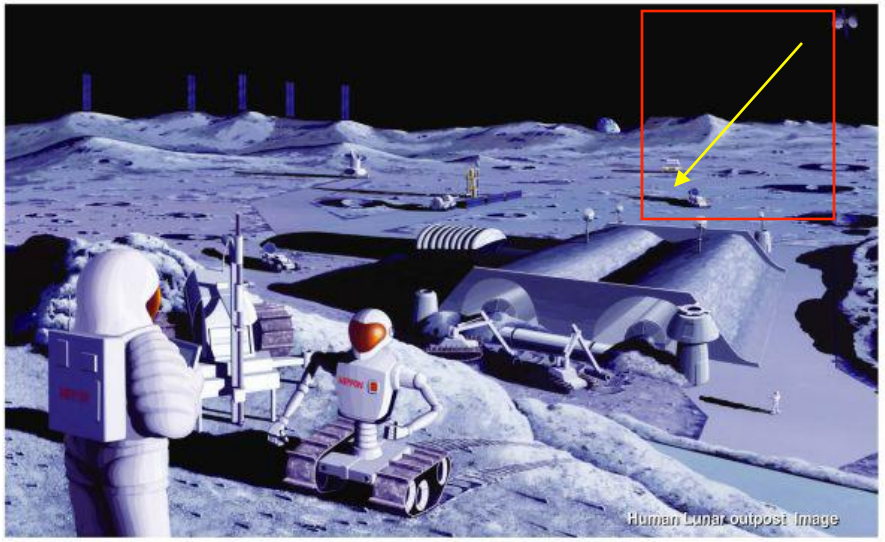
Laser Power Transmission for Lunar Exploration

Shackleton crater, a potential candidate for water ice

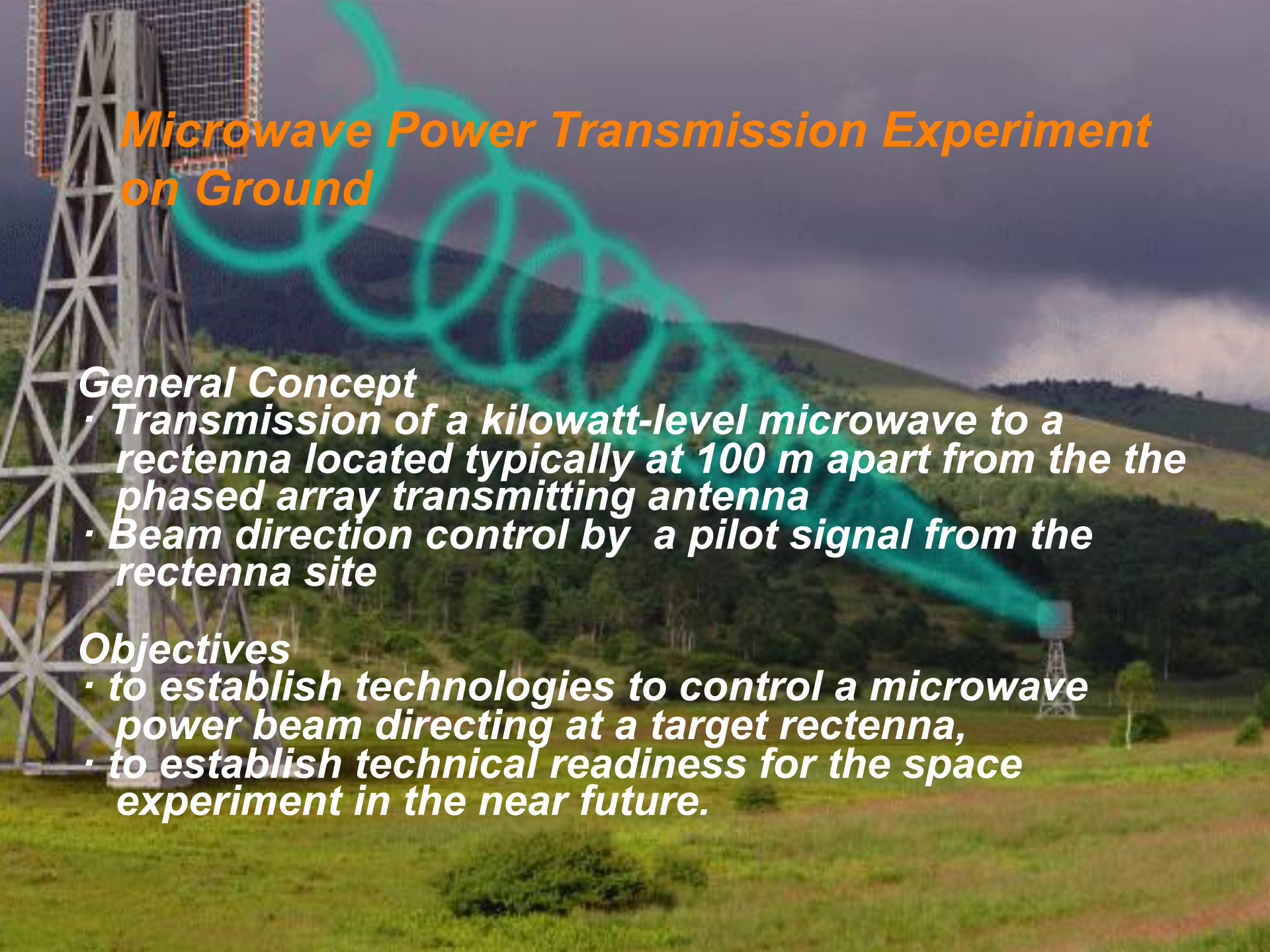




Power transmission to a rover in the shadow inside the crater



Power transmission from lunar orbit to lunar base

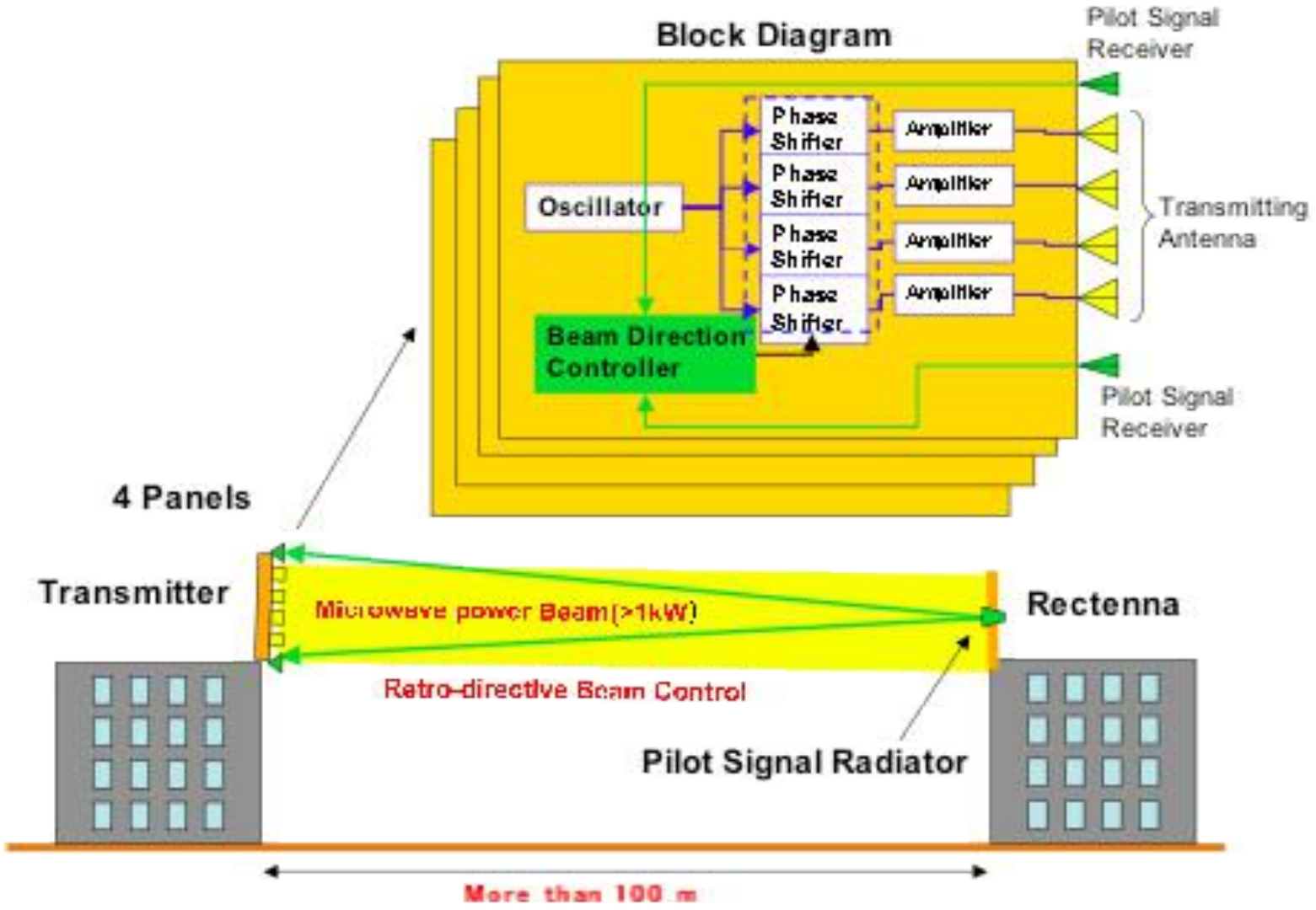


Microwave Power Transmission Experiment on Ground

General Concept
- Transmission of a kilowatt-level microwave to a rectenna located typically at 100 m apart from the 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.

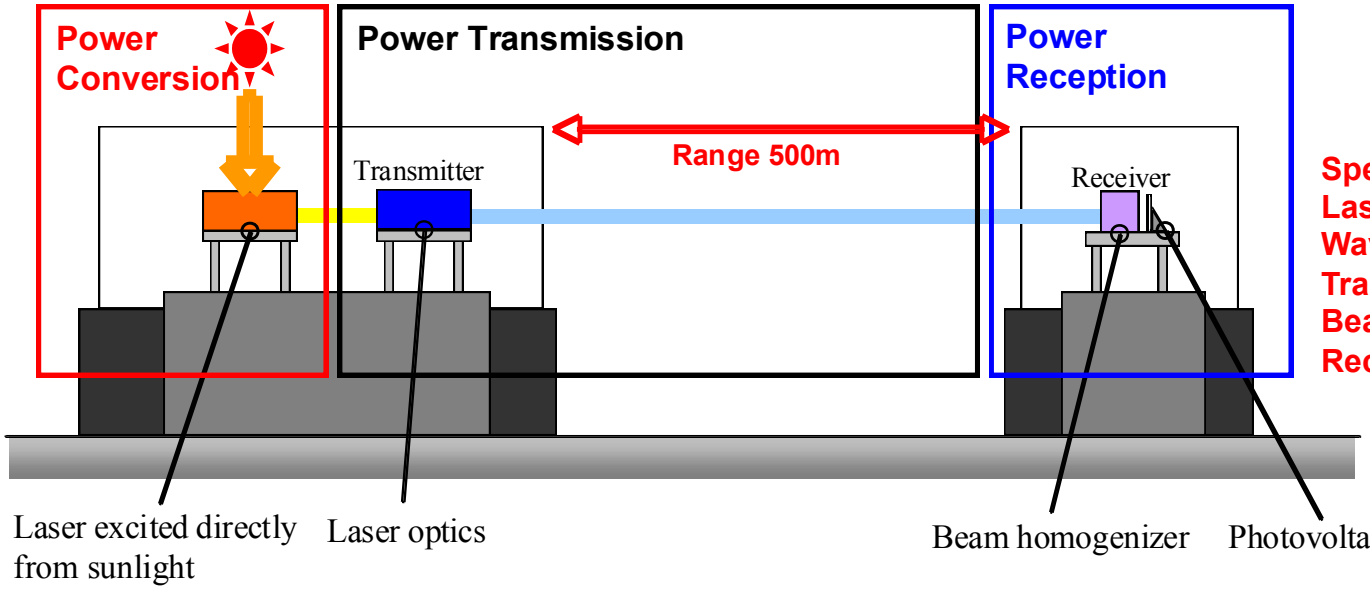
Configuration of Microwave Power Transmission Experiment



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	0.65λ spacing
Microwave beam control	Retro-directive control using a pilot signal from rectenna site
Phase control accuracy	5 bits
Rectenna configuration	16 flexible panels, 2m x 2m/panel, DC conversion efficiency 75%
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

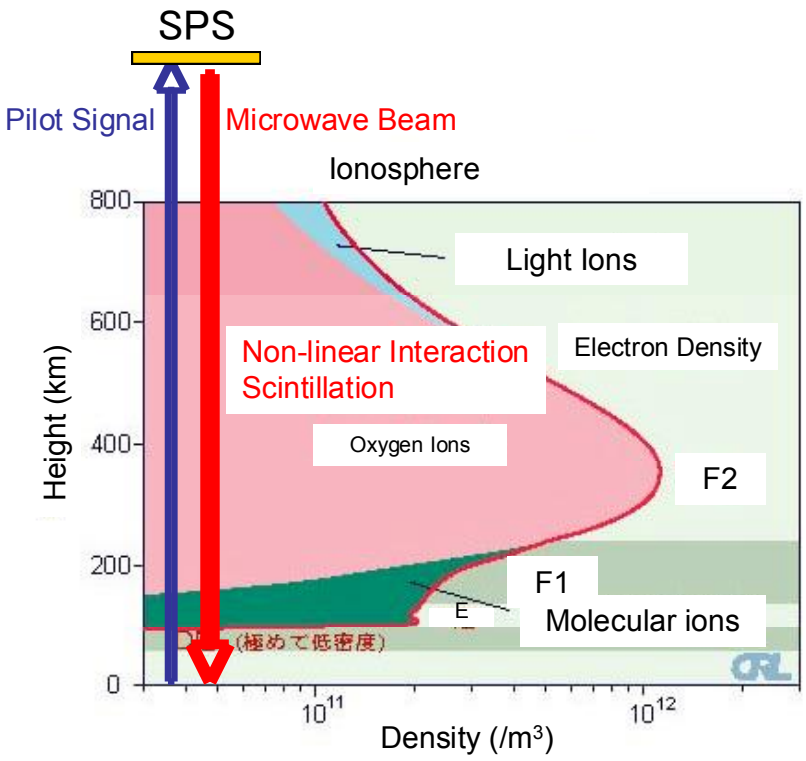
Microwave Transmission Experiment in Space

(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,

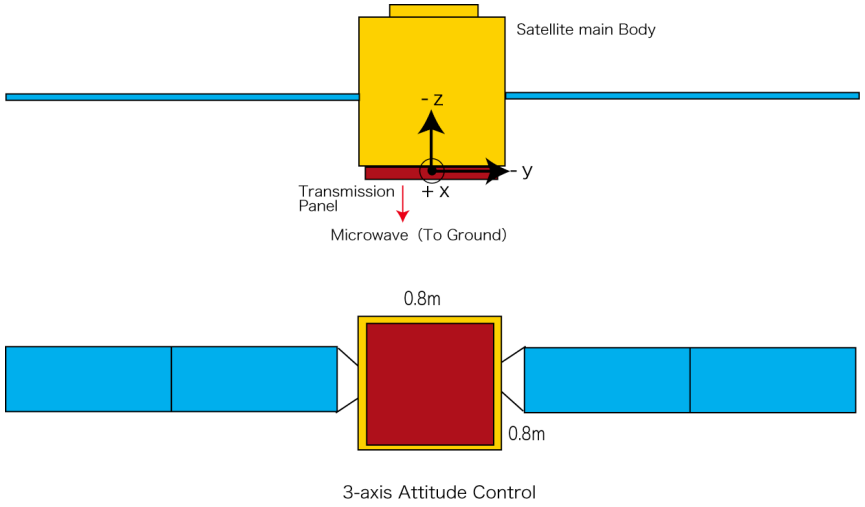
(4) demonstration of the electromagnetic compatibility with the existing communication infrastructure.



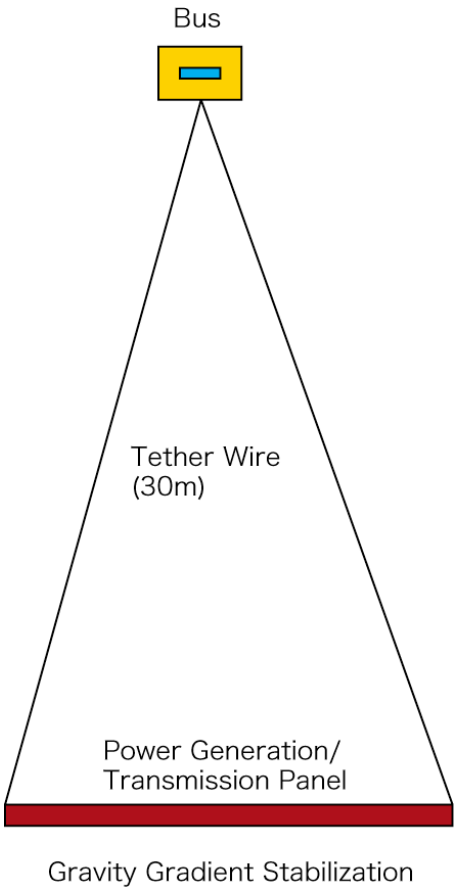
System Characteristics of Demonstration Model

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

Experimental Configuration using Small Satellite

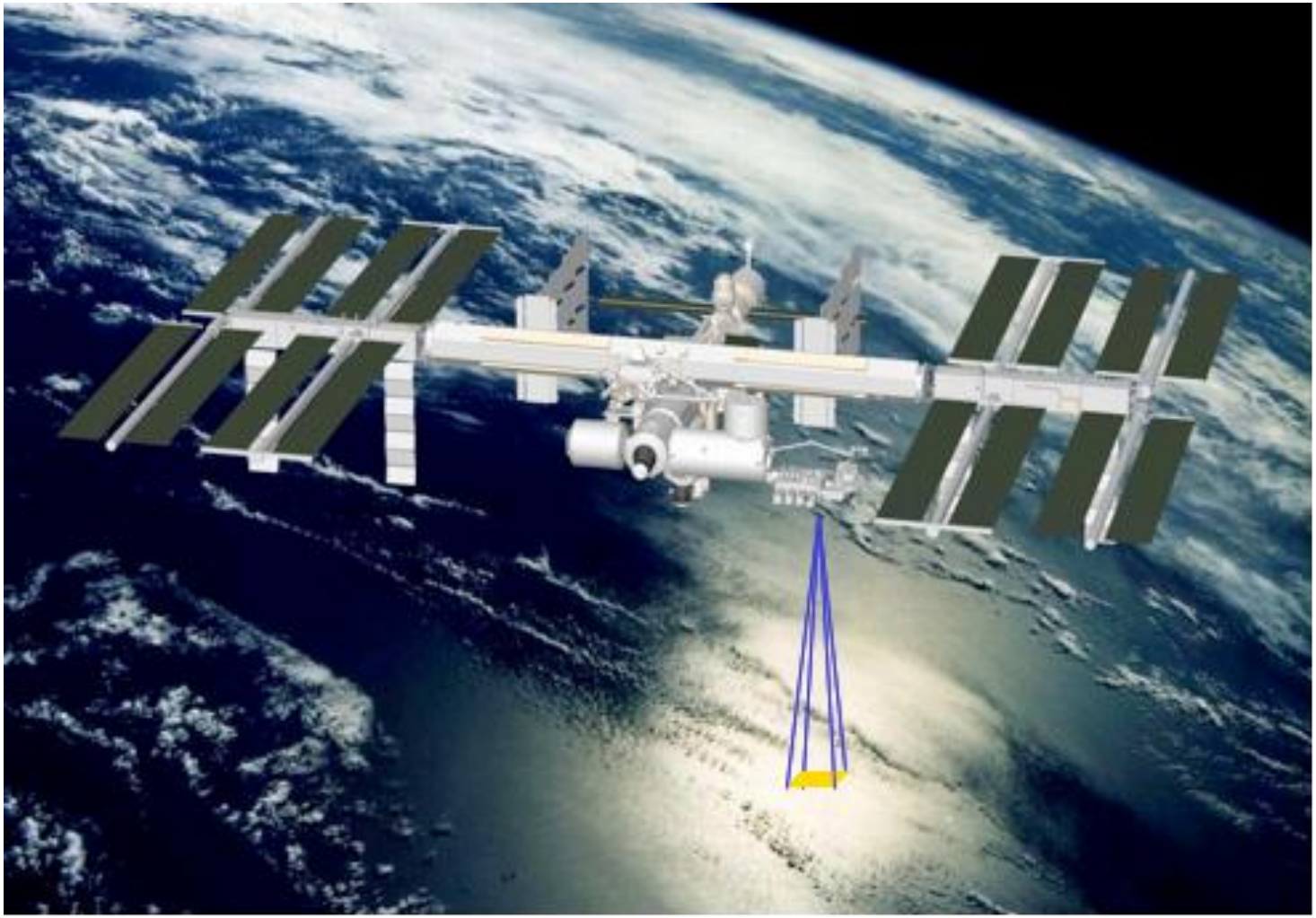


Option A（950W, 65 kg）

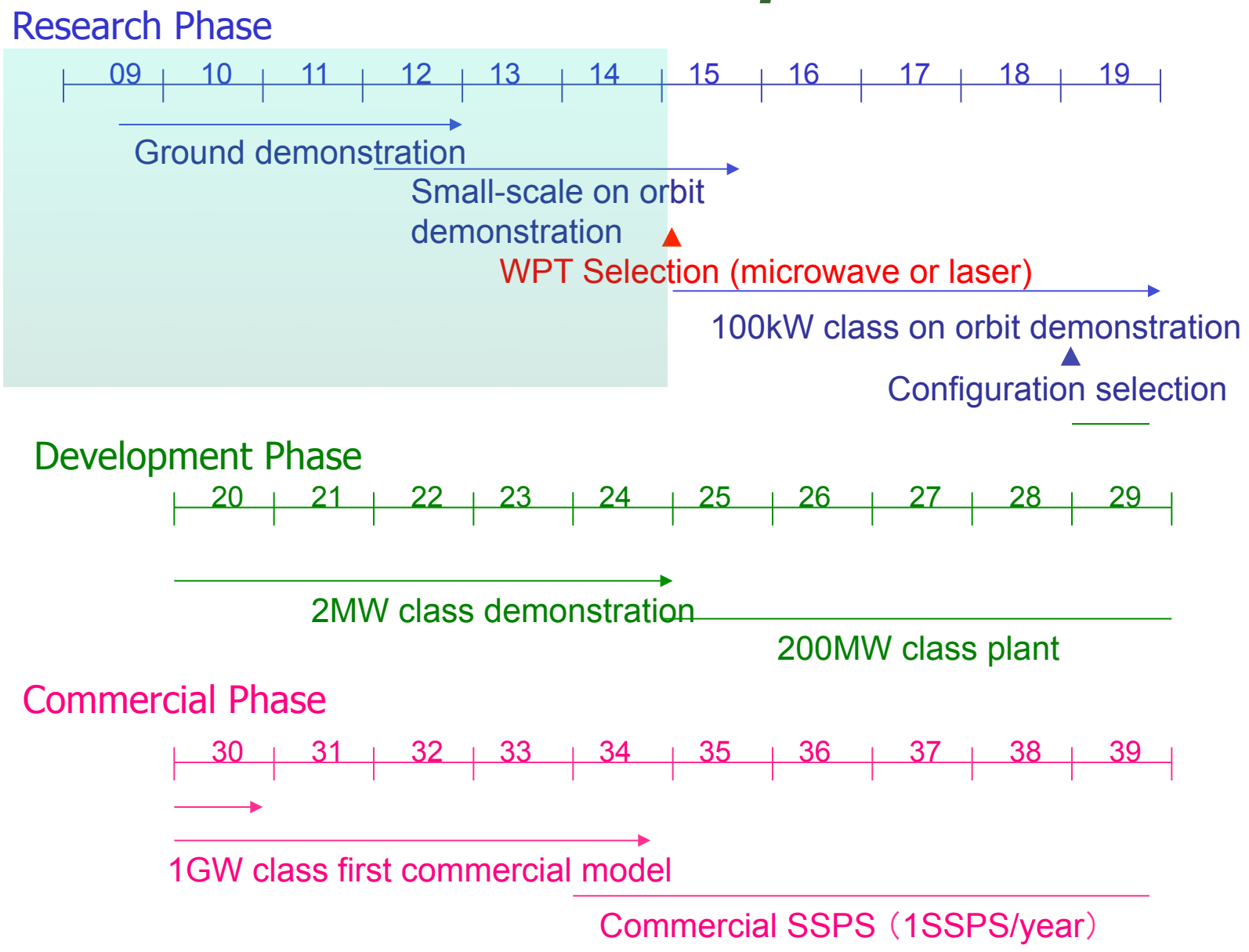


Option B（3800W, 200 kg）

Experimental Configuration using JEM on Space Station

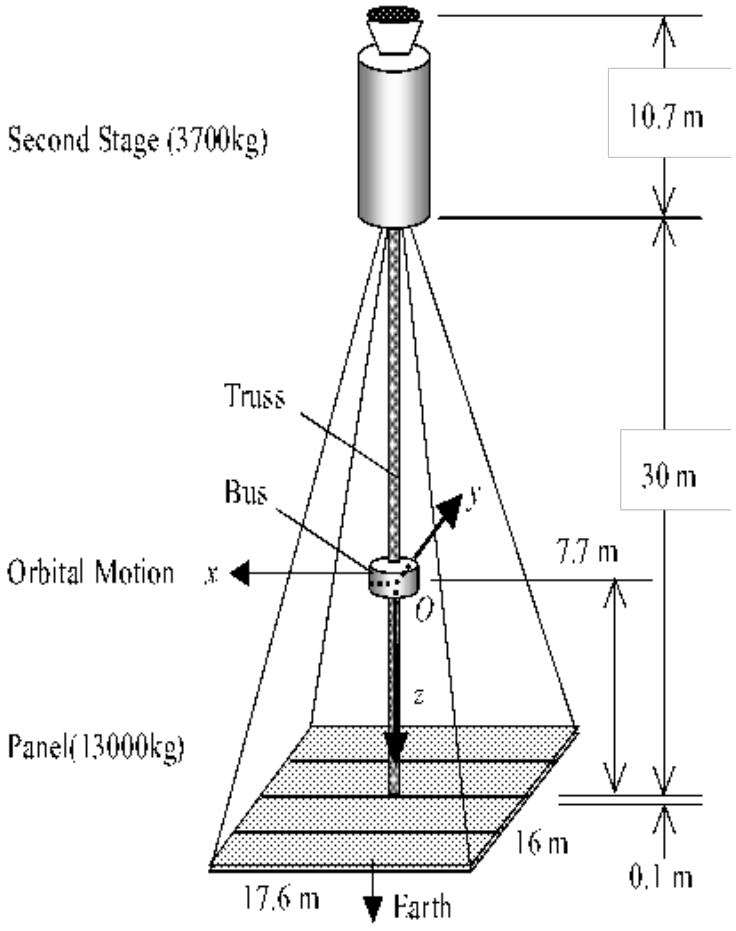


Roadmap

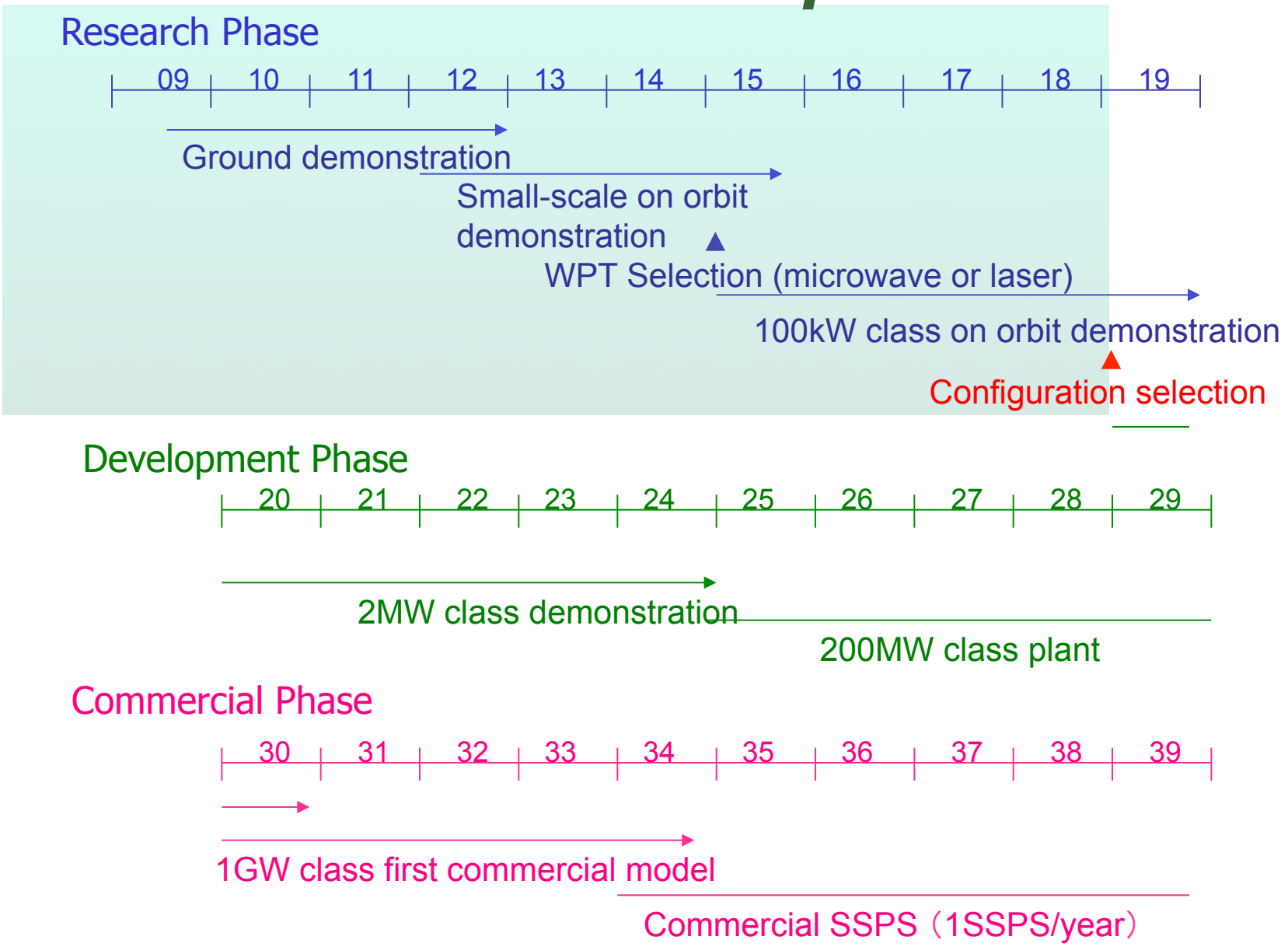

Research Phase
09
10
11
12
13
14
15
16
17
18
19
Ground demonstration
Small-scale on orbit demonstration
WPT Selection (microwave or laser)
100kW class on orbit demonstration
Configuration selection
Development Phase
20
21
22
23
24
25
26
27
28
29
2MW class demonstration
200MW class plant
Commercial Phase
30
31
32
33
34
35
36
37
38
39
1GW class first commercial model
Commercial SSPS（1SSPS/year）

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)*



Roadmap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200MW class plant
Commercial Phase
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1GW class first commercial model
Commercial SSPS（1SSPS/year）

Verification Matrix

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/ atomosphere transmission	-	1kW/m^2			
Power Transmission	(Test Rectenna kW)	-	Small Rectenna 10kW	Large Rectenna 2MW	Large Rectenna 200MW
SSPS Total Function	-	-	10kW	2MW	200MW
Power for Practical Use	-	-	-	2MW	200MW

Summary and Conclusion

- Three commercial SSPS 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 will be conducted within several years, both for microwave and laser.
- Immediately after or during the ground demonstration experiment, we will start a small-scale experiment in orbit to transmit a 1 kW class microwave power to the ground. Essential technologies for large space structure are hopeully demonstrated in this phase.
- 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 now reflected on the basic plan on space development by the government's space development strategy headquarter.