Development Status of SPS in China

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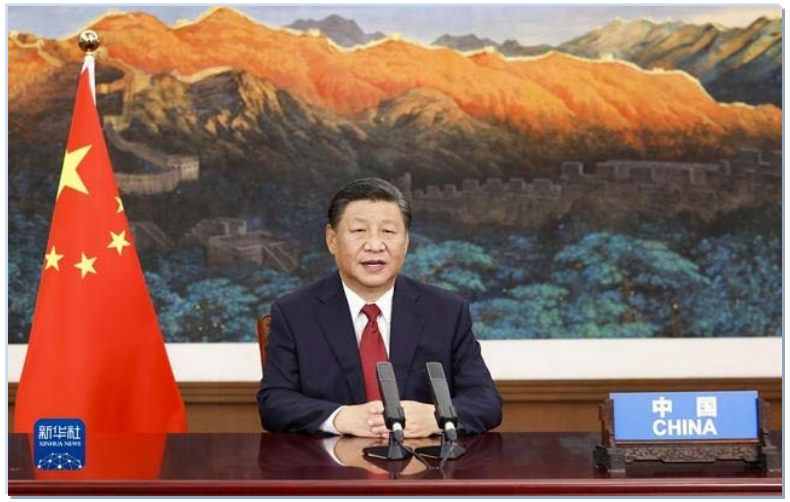
Contents

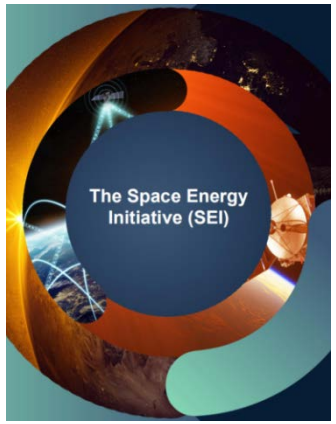
Net Zero CO_2 emission – for the future of our planet

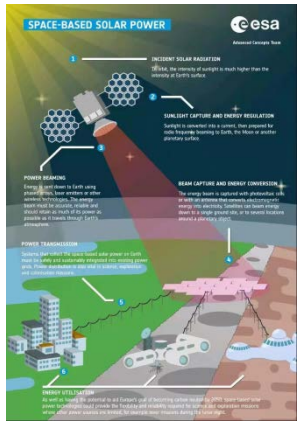
- In 2020, President Xi Jinping announced that China would strive to peak CO_2 emissions before 2030, and achieve carbon neutrality before 2060.
- Climate change is a challenge for all of humanity. Net Zero is an urgent goal and a big challenge for all countries.
- The intermittency of the current renewable technologies makes them are not able to meet the challenges.
- There is an urgent need to develop new sources of clean energy that are sustainable, affordable, secure and scalable.

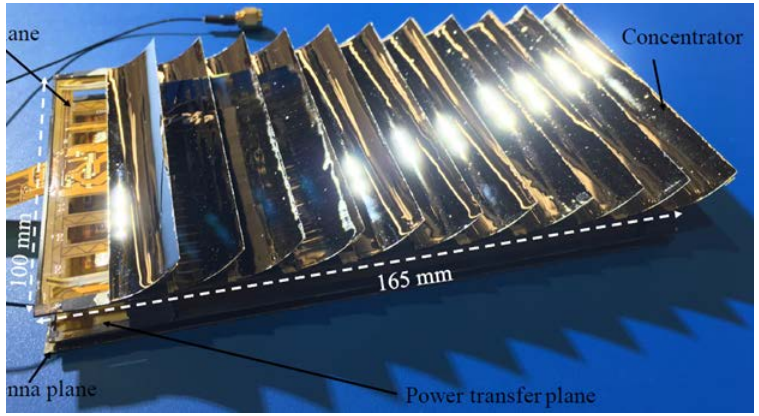


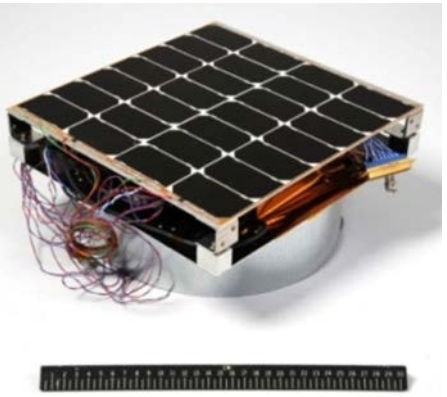
Great news of SPS

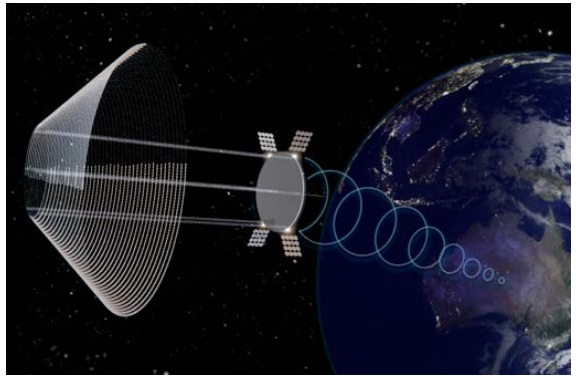
- Positive support from government and private business
- Innovative SPS concepts
- Rapid technology progress

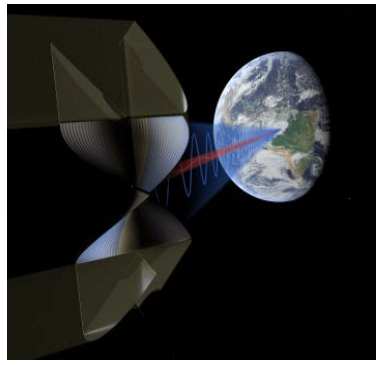


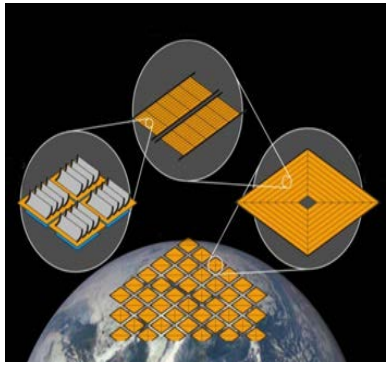












Speedy progress of space industry

- High capability and low cost of launcher
- Large scale and low cost production of spacecraft

Falcon9

- Payload：22t
- Quoted Price：$62M
- Cost：$20M

Falcon Heavy

- Payload：60t
- Quoted Price：$90M
- Cost：$30M

Starship

- Payload：150t
- Quoted Price：?
- Cost Goal：$3M

Starlink

- Mass：250kg
- Cost：$0.5M

Contents

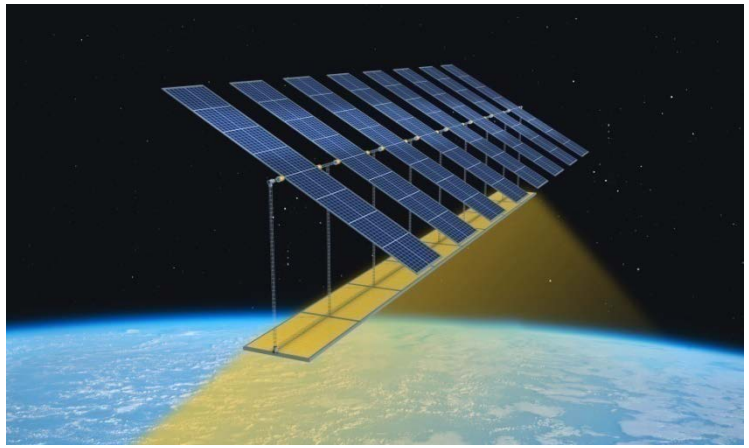
2.1 Research Activities

- China National Space Administration(CNSA) has supported the research of SPS system and key technology since 2008 and will support continuously in the next several years.
- National Natural Science Foundation of China(NSFC) has supported the fundamental research since 2015.

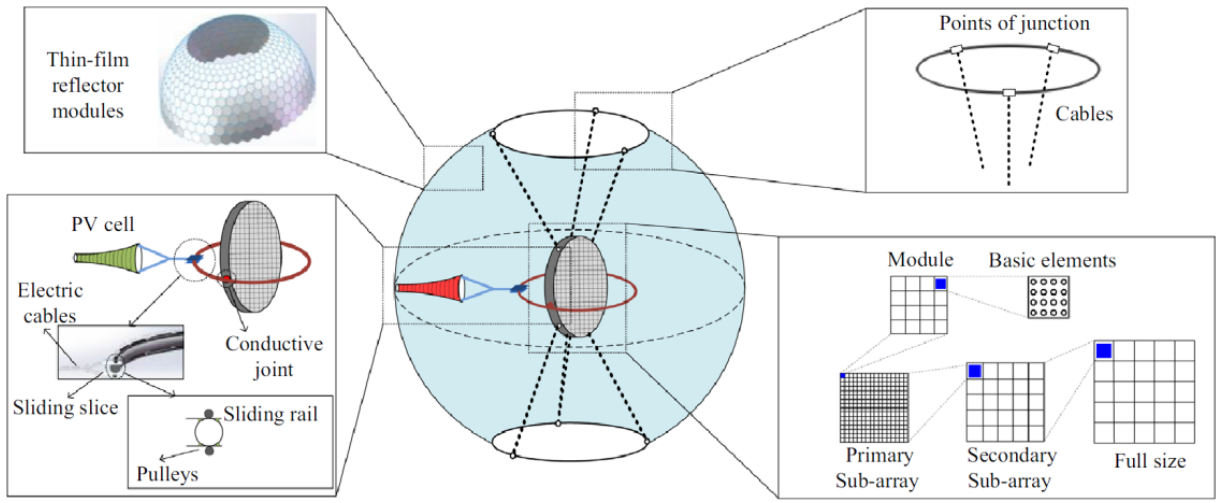
2. Development Status of SPS in China

- **New Concepts**

MR-SPS, CAST, 2014



MMR-SPS, CAST, 2021

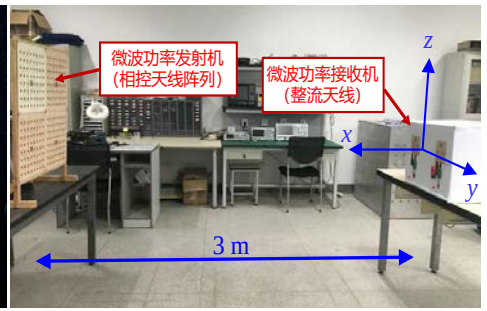


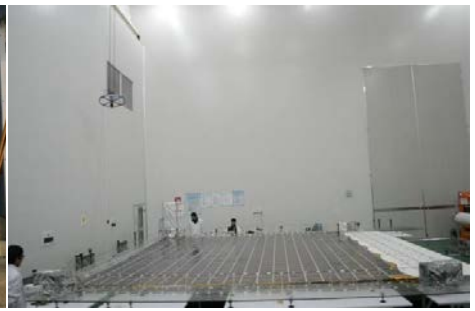
SSPS-OMEGA, Xidian University, 2014

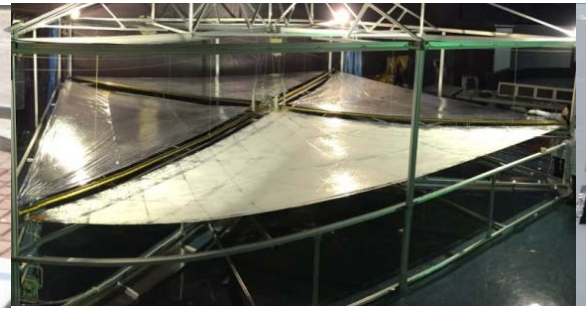
2. Development Status of SPS in China

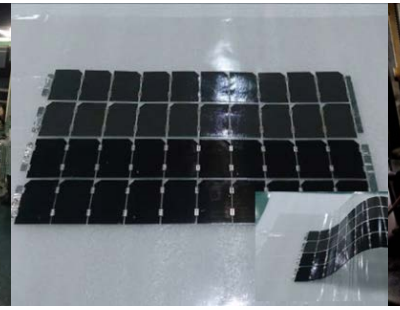
Technologies research

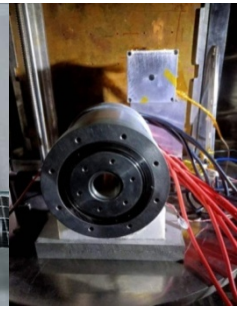
- **MPT is being studied and demonstrated as the most important technologies by CAST, Xidian University, Sichuan University, Chongqing University and others.**
- **LPT is being studied as the flexible long distant power transmission application by CAST, Beijing Institute of Technology and others.**
- **Advanced solar cells, high power electric equipment and large scale structure are being studied by SAST, CAST and others.**





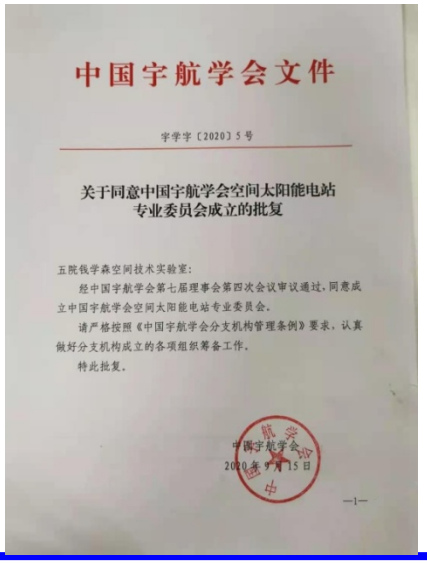






2. 2 Committee of Space Solar Power, Chinese Society of Astronautics

- On March 26, 2021, CSSP-CSA was established in Beijing.
- The committee invites 7 academicians as consultants, 68 committee members from 37 research institutions.
- Prof. Ming Li was elected as the chairman of the committee.
- The first academic conference is delayed and will be held in Chongqing. Over 200 persons and 100 papers are expected.



中国宇航学会文件

宇学字〔2020〕5号

关于同意中国宇航学会空间太阳能电站专业委员会成立的批复

五院钱学森空间技术实验室：

经中国宇航学会第七届理事会第四次会议审议通过，同意成立中国宇航学会空间太阳能电站专业委员会。

请严格按照《中国宇航学会分支机构管理条例》要求，认真做好分支机构成立的各项组织筹备工作。

特此批复。

中国宇航学会

2020年7月15日

2. 3 Experiment Bases

- A Space Solar Power Experiment Base has being set up in ChongQing since December 6, 2018. The investment will be over $15 millions. Research fields will include Microwave Power Transmission, Laser Power Transmission, High Voltage Electric Technology, Environment Effect of High power WPT, etc.
- The infrastructure of the Space Solar Power Experiment Base will be completed soon. The basic experimental facilities will be established this year.

2. 3 Experiment Bases

- The ZhuRi (Chase the Sun) Project was started in Dec. 2018. A full system, ground experimental demonstration system based on SSPS-OMEGA concept has been built.

- whole energy chain demonstration:
  - Sunlight(concentrated) – DC – MW – Transmission – DC
  - Transmission distance：100m
  - Output DC power： 1kW
  - Transmission efficiency： 20%(DC-DC, goal).

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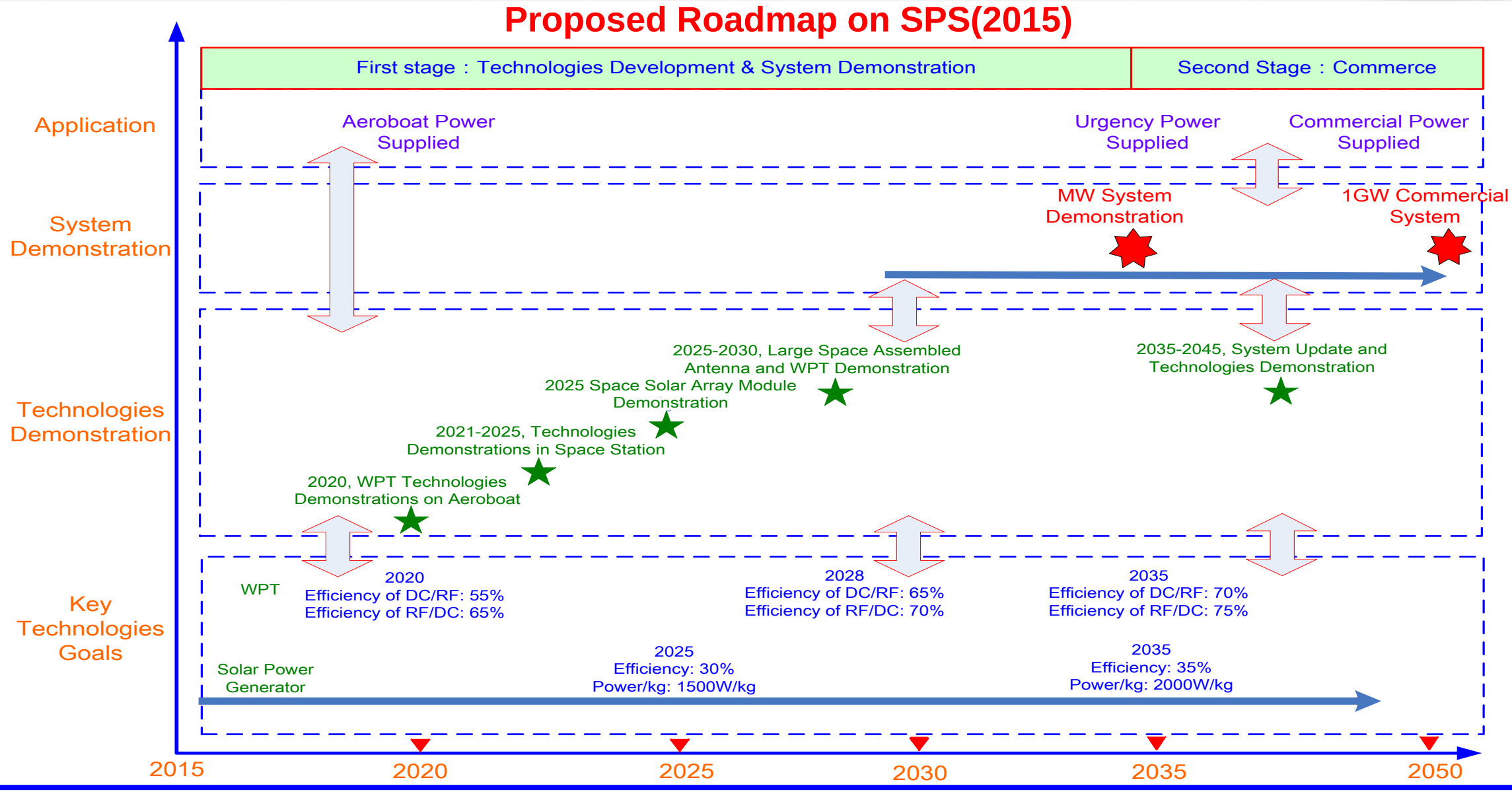
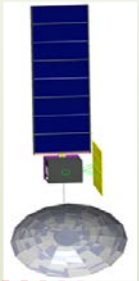
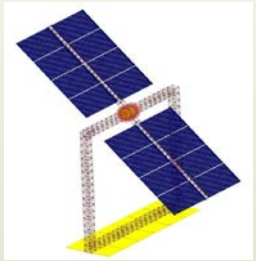
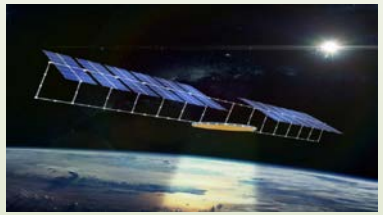
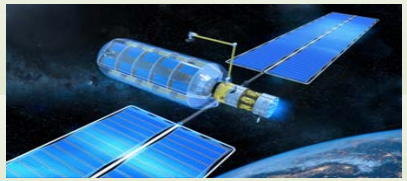
3. Proposed roadmap on SPS in China



3. Proposed roadmap on SPS in China

Revised Roadmap on SPS(draft)

	2026	2030	2035	2050
Mission Objective	High Power Electric Generation and WPT Demonstration Mission	GEO High Power WPT Demonstration Mission	MW Pilot Space Solar Power	GW Space Solar Power
				
Character	• ¼ Solar array module • MPT module • Low power LPT • No assembly	• ½ Solar sub-array • Large MPT antenna • Middle power LPT • Simple assembly	• Whole solar array • 100m MPT antenna • High power LPT • Complex assembly	• Hugh solar array • Km MPT antenna • High power LPT • Extremely Complex assembly
Typical Specification	• Power: 10kW level • Voltage: 500V level • MPT antenna: m scale • MPT distance: 400km	• Power: 500kW level • Voltage: 2kV level • MPT antenna: 10m scale • MPT distance: 36000km	• Power: 20MW level • Voltage: 5kV level • MPT antenna: 100m scale • MPT distance: 36000km	• Power: 2GW level • Voltage: 20kV level • MPT antenna: km scale • MPT distance: 36000km
Heavy Launcher			• Payload mass: ≥ 50t • Envelope diameter: ≥ 8m • Envelope height: ≥ 20m	• Payload mass: ≥ 100t • Envelope diameter: ≥ 10m • Envelope height: ≥ 25m • Resuable
Reusable OTV			• Payload mass: ≥ 50t • Thrust: ≥ 15N • Power: ≥ 400kW • Resuable	• Payload mass: ≥ 100t • Thrust: ≥ 50N • Power: ≥ 1MW • Resuable
Assembly in Space		• Assembly site: LEO • Assembly operator: robot • Number of robots: 2	• Assembly site: GEO • Assembly operator: robot • Large support platform	• Assembly site: GEO • Assembly operator: robot • Ultra large platform • Manufacture in GEO

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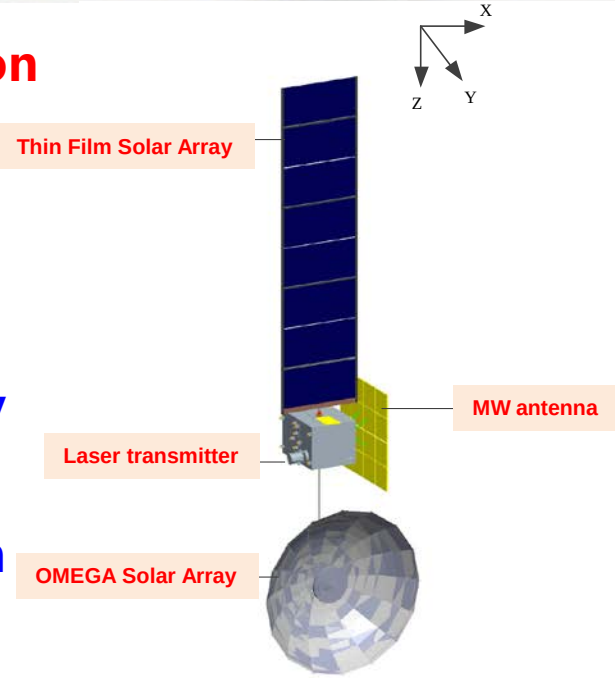
1. Background
2. Development of SPS in China
3. Proposed roadmap on SPS
4. **Possible Demonstration Projects**

4. Possible Demonstration Projects

Mission 1: High Power Electric Generation and WPT Demonstration Mission

Includes 2 spacecraft in LEO and receiving system on ground to evaluate the validity of some key technologies of SPS in space.

- **Design principle:**
  - The emphasize of the mission is to validate the theoretical energy chain and long distance beam control precision;
  - The scheme and main specifications of the solar array are based on the solar array module design of MW SPS;
  - The structure, circuit, thermal control and main electric specifications are based on the design of antenna module of MW SPS;
  - The size of microwave antenna is the tradeoff of considering the power, density and beam control.
  - The LPT is a scale full system to transmit power to the receiver on spacecraft and on ground .



Primary spacecraft

Receiving spacecraft

4. Possible Demonstration Projects

- **Mission specifications(draft)**

(1) Primary spacecraft

- MPT system
  - Frequency: 5.8GHz
  - RF Power: 4kW
  - Efficiency: 50%
  - Beam precision: 0.2°
- LPT system
  - Wavelength: 1064nm
  - Laser Power: 1kW
  - Efficiency : 35%
  - Beam precision : 5urad
- Thin film solar array
  - Output DC power: 10kW
  - Voltage: 500V
- Concentrator solar array
  - Output DC power: 10kW
  - Concentration ratio: 4

2) Receiving spacecraft

- Laser receiving
  - Distance: 10km-50km
  - Laser density: 1-3 sunlight
  - Laser cell efficiency (high) : 35%

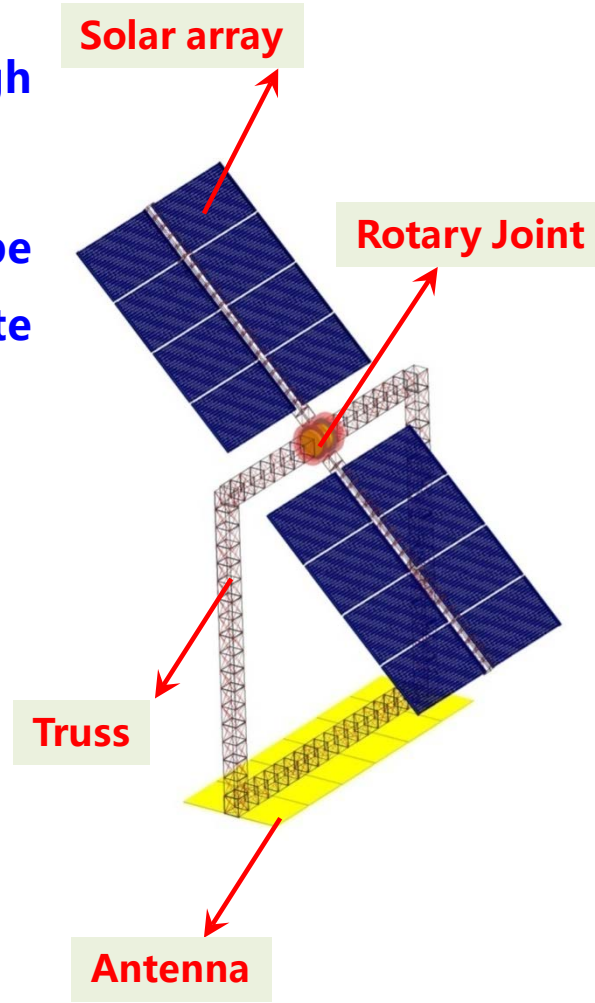
3) Receiver on ground

- MPT receiving
  - Distance : 400km
  - Microwave density : 30μW/m^2
  - Rectenna efficiency : 6%
- LPT receiving
  - Distance : 400km
  - Laser cell efficiency (low) : 20%

Mission 2: GEO High Power WPT Demonstration Mission

Include 1 spacecraft in GEO and receiving system on ground to evaluate high power electric system, very long distant WPT and assembly technologies in space.

The modules are launched to LEO and assembled. The WPT experiment will be conducted in LEO firstly. Then the spacecraft will transfer to GEO and demonstrate WPT in GEO.



Design principle :

- The solar sub-array, the antenna module and the truss module are based on the design of MW SPS ;
- The conductive rotary joint is similar to the MW SPS ;
- The assembly interface is similar to the MW SPS ;
- The basic assembly technologies needs to be demonstrated ;
- For the MPT in LEO, the power density on ground is similar to the MW SPS;
- For the MPT in GEO, the power density on ground is similar to Mission 1.

4. Possible Demonstration Projects

- **Mission specifications(draft)**

(1) Spacecraft

- MPT system
  - Frequency： 5.8GHz
  - RF Power： 100kW
  - Efficiency： 60%
  - Beam precision： 0.01°
- LPT system
  - Wavelength： 1064nm
  - Laser Power： TBD
  - Efficiency： 37%
  - Beam precision： 1urad
- Thin film solar array
  - Output power(solar array module)： 50kW
  - Voltage： 500V
  - Total DC power: 400kW
- High power PMAD
  - Power of the rotary joint : 400kW
  - Voltage conversion : 500V/2kV
  - Efficiency: 97%

2) Receiving system

- MPT
  - Distance (GEO) : 36000km
  - Microwave density (GEO) : 30μW/m^2
  - Rectenna efficiency (GEO) : 8%
  - Distance (LEO) : 400km
  - Microwave density (LEO) : 80mW/m^2
  - Rectenna efficiency (LEO) : 60%
- LPT
  - Distance : 36000km

Thank you very much!

Please Contact: houxinbin525@163.com