



CLEAN ENERGY INNOVATION
THE LUNAR RING
LUNAR SOLAR POWER GENERATION

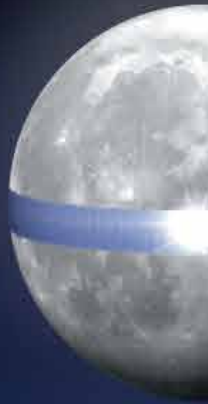
The Energy Paradigm Shift Opens the Door to a Sustainable Society

A shift from economical use of limited resources to the unlimited use of clean energy is the ultimate dream of all mankind.

The LUNA RING, our lunar solar power generation concept, translates this dream into reality through ingenious ideas coupled with advanced space technologies.

Virtually inexhaustible, nonpolluting solar energy is the ultimate source of green energy that brings prosperity to nature as well as our lives.

Shimizu Corporation proposes **The LUNA RING** for the infinite coexistence of mankind and the Earth.





The LUNA RING



Lunar Solar Power Generation

Electric power generated by a belt of solar cells around the lunar equator will be transmitted and beamed to the Earth from the near side of the Moon* (* the side that always faces the Earth)

Mega-Scale Solar Power Generation on the Lunar Surface

- ✦ Eliminates inefficiency due to bad weather
- ✦ Achieves 24/7 continuous power generation

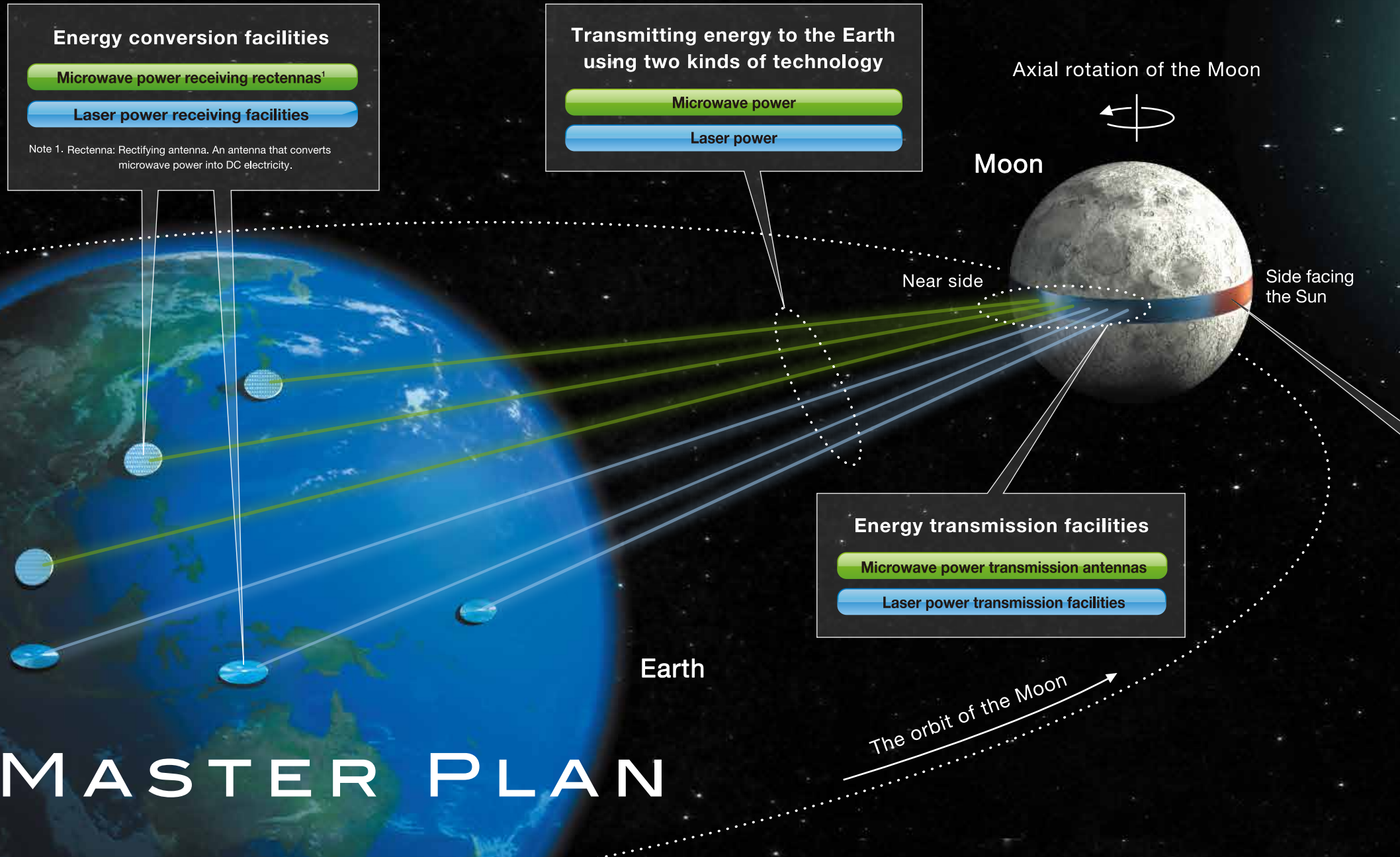


Energy Available for Use Anywhere on the Earth

- ✦ Fulfills all energy needs
- ✦ Realizes a clean energy society



How Lunar Solar Energy Reaches the Earth



Transmitting Energy from the Moon to the Earth

Sun



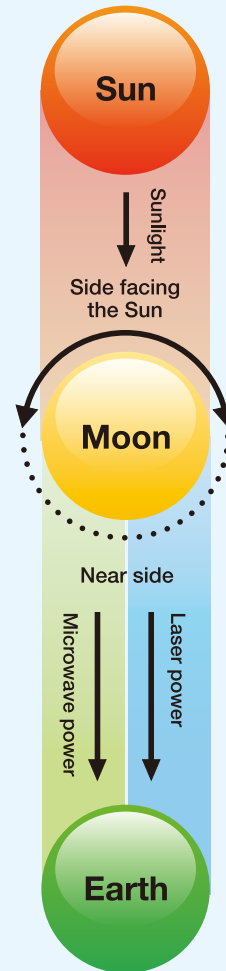
Solar power generation facilities

Lunar solar cells

Electric power cables

What is the lunar equator?

An imaginary line that circles the lunar surface at the Moon's center, perpendicular to its axis.



Sunlight
(Solar energy)

The lunar equator is constantly exposed to a steady amount of energy from the Sun.

Lunar solar cells
(The Solar Belt)

Electric power cables

Energy transmission facilities
(Facilities transmitting energy to the Earth)

Sunlight is converted into electricity using solar cells of the electric power generation facilities located on the lunar equator. The electric power is transmitted via cables to the near side of the Moon where it is converted into microwave power and laser power in order to transmit energy to the Earth.

Energy conversion facilities
(Facilities converting energy from the Moon into electricity and producing hydrogen)

Supply energy to the entire world

At ground energy conversion facilities, the microwave power and laser power transmitted from the Moon are converted into electric power that is supplied to grids. Alternatively, energy is converted into hydrogen for use as fuel, or stored. In this way, a world where all human beings can use energy equally will be realized.

The Sun Revitalizes the Earth

The Future that The LUNA RING Promises



Shift from Fossil Fuels to Clean Energy

No use of fossil fuels as energy sources



Global conversion to a hydrogen society¹



Note 1. Hydrogen society: A "clean" society no longer dependent on coal and oil because it uses hydrogen, which produces only water when burned, for energy needs from electric power generation to heating

Unlimited Clean Energy that can be Used in Vast Quantities

Realization of a complete recycling society



Stable supply of water and food



Creation of new industries



Clean Energy in Every Corner of the World

Mitigation of global warming



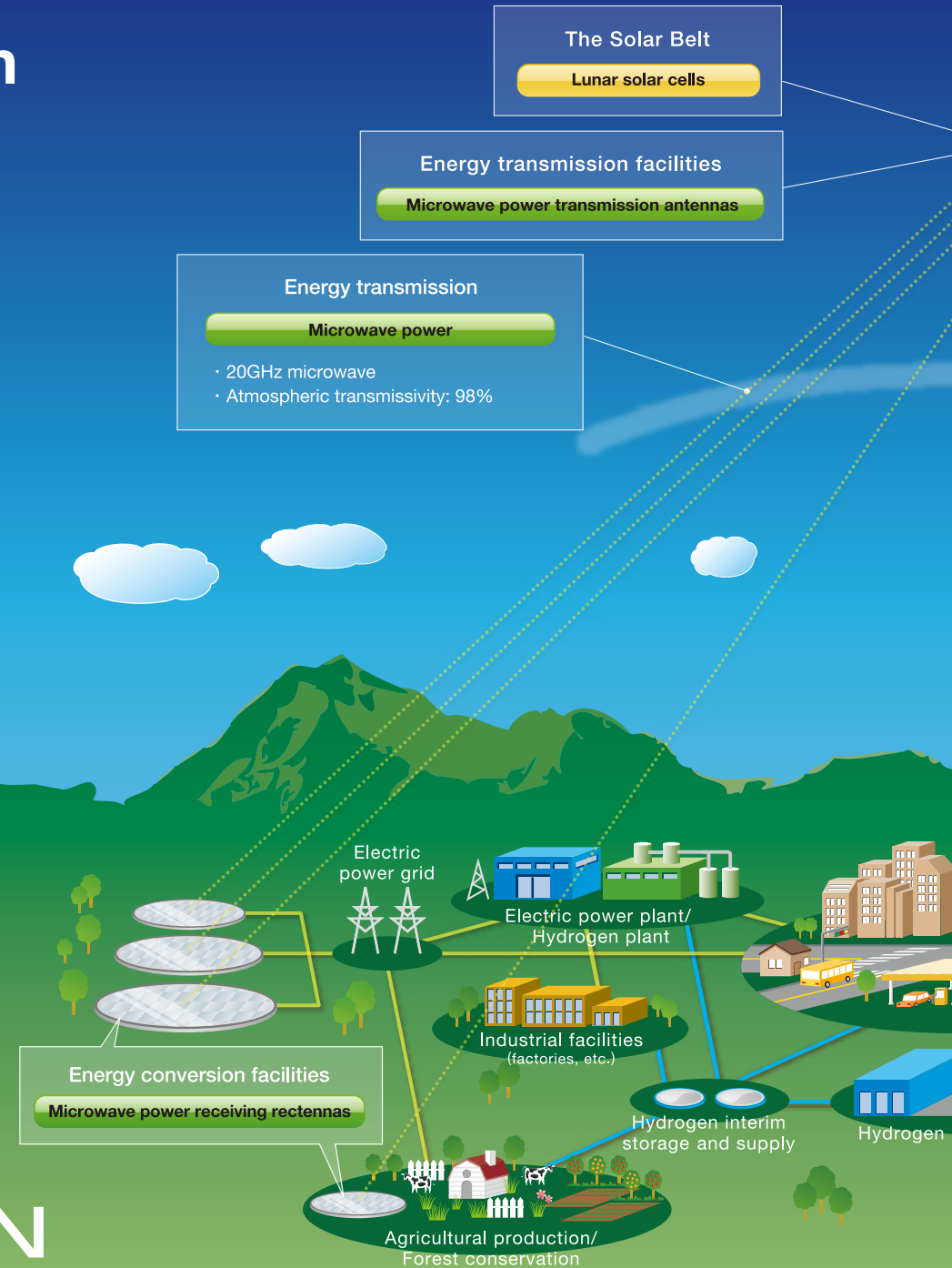
Deterrence of environmental destruction

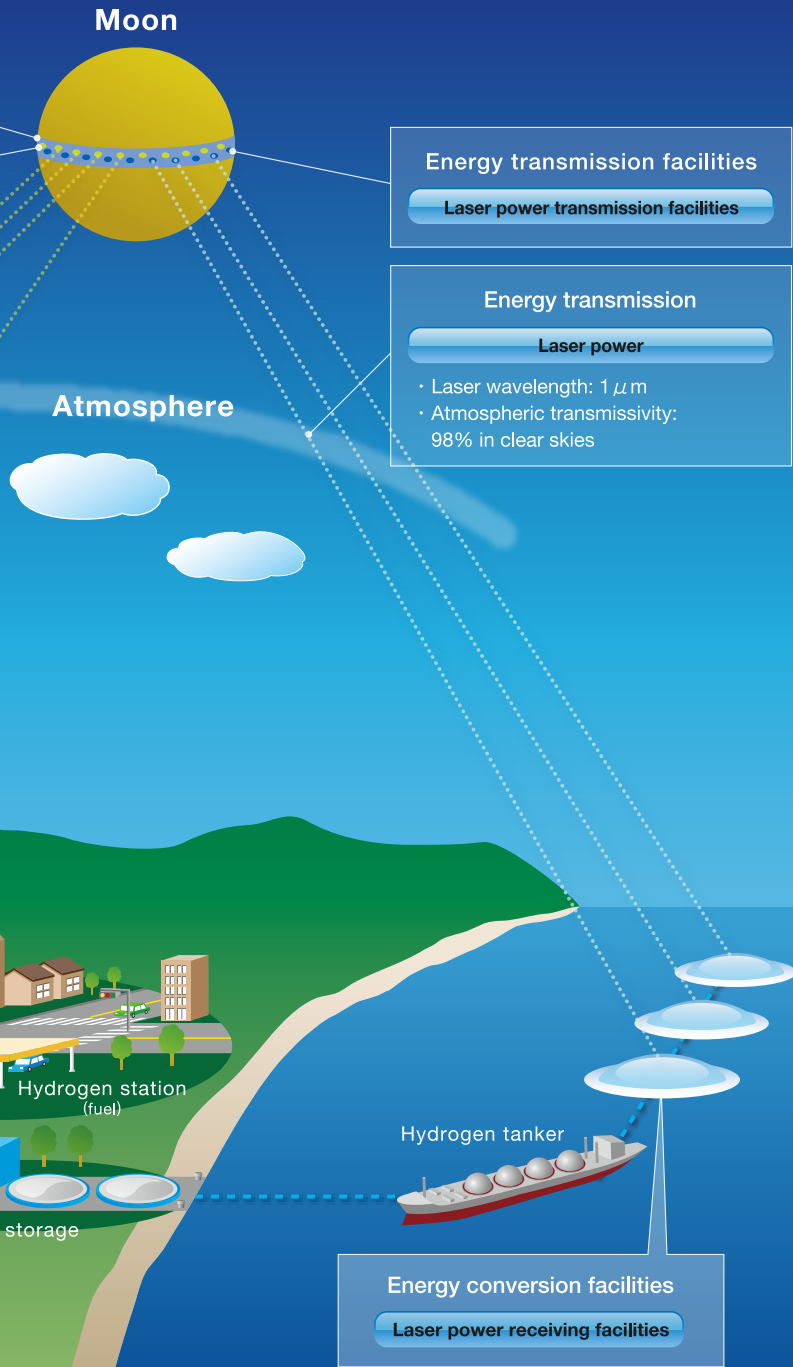


Improvement of life quality



MASTER VISION

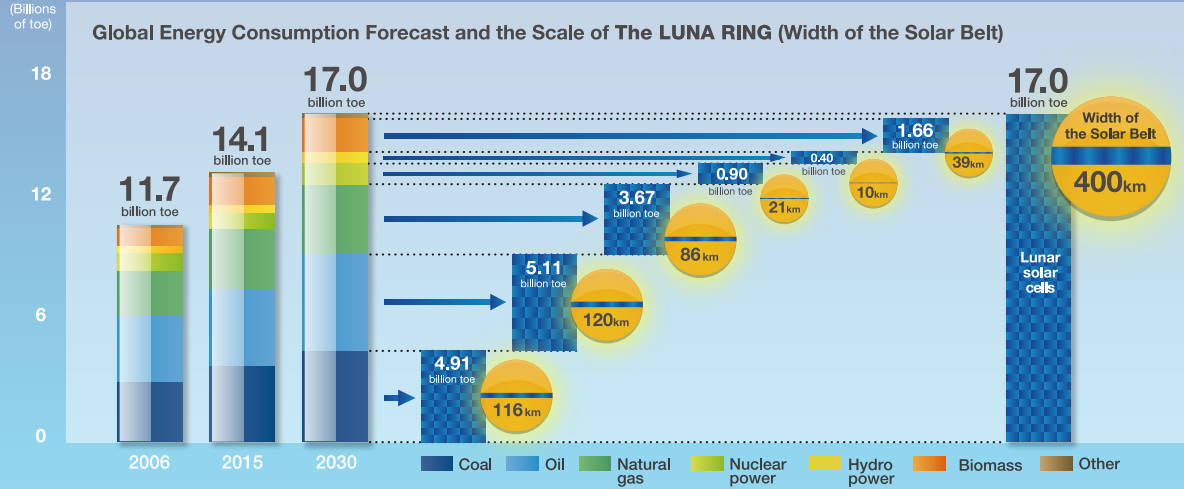




When the Lunar Solar Cells Surpass Fossil Fuels

The 400km-wide LUNA RING will supply the energy the world needs² in 2030.

Note 2. The global energy demand forecast for 2030 is 17 billion tonnes of oil equivalent (toe). Source: IEA World Energy Outlook 2008

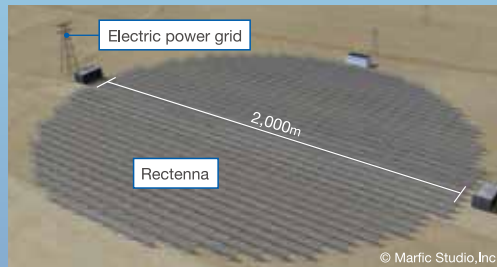


Microwave power receiving rectennas

Can be located on the Earth.
Rectennas are large-scale arrays of antennas.

From microwave to electric power

- Semiconductors and inverters convert microwave power into electric power.
- The electric power produced is supplied to the grid.
- The electric power is also used to produce hydrogen for fuel by electrolysis.



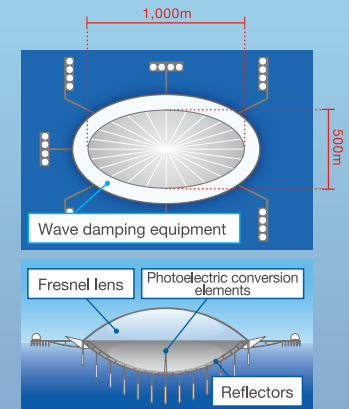
Laser power receiving facilities

Located in equatorial regions, where there is little cloud cover.

Offshore facilities are floated and tied loosely as the laser beam actively tracks the facilities' location.

From laser to electric power

- Laser beams are concentrated by a fresnel lens and numerous mirrors to generate power using photoelectric conversion elements.
- Hydrogen is produced from sea water and shipped for storage.
- The thermal energy of laser beams and sunlight generates additional electric power.



The Solar Belt Made from Lunar Resources -Constructing a lunar

✦ Exploiting Lunar Resources

Lunar resources will be used to the fullest extent possible in constructing the Solar Belt.

✦ Lunar soil can be used to make

Ceramics

Concrete

Glass

Solar cells

Oxygen

Water

● Construction materials

Water can be produced by reducing lunar soil with hydrogen that is imported from the Earth. Cementing material can also be extracted from lunar resources. These materials will be mixed with lunar soil and gravel to make concrete. Bricks, glass fibers and other structural materials can also be produced by solar-heat treatments.

✦ Robotic Construction

Robots will play a vital role in construction on the lunar surface. They will be tele-operated 24 hours a day from the Earth.



● Construction and resource extraction

Robots will perform various tasks on the lunar surface, including ground leveling and excavation of hard bottom strata.



Source: NASA

● Assembling units in space

Machines and equipment from the Earth will be assembled in space and landed on the lunar surface for installation.

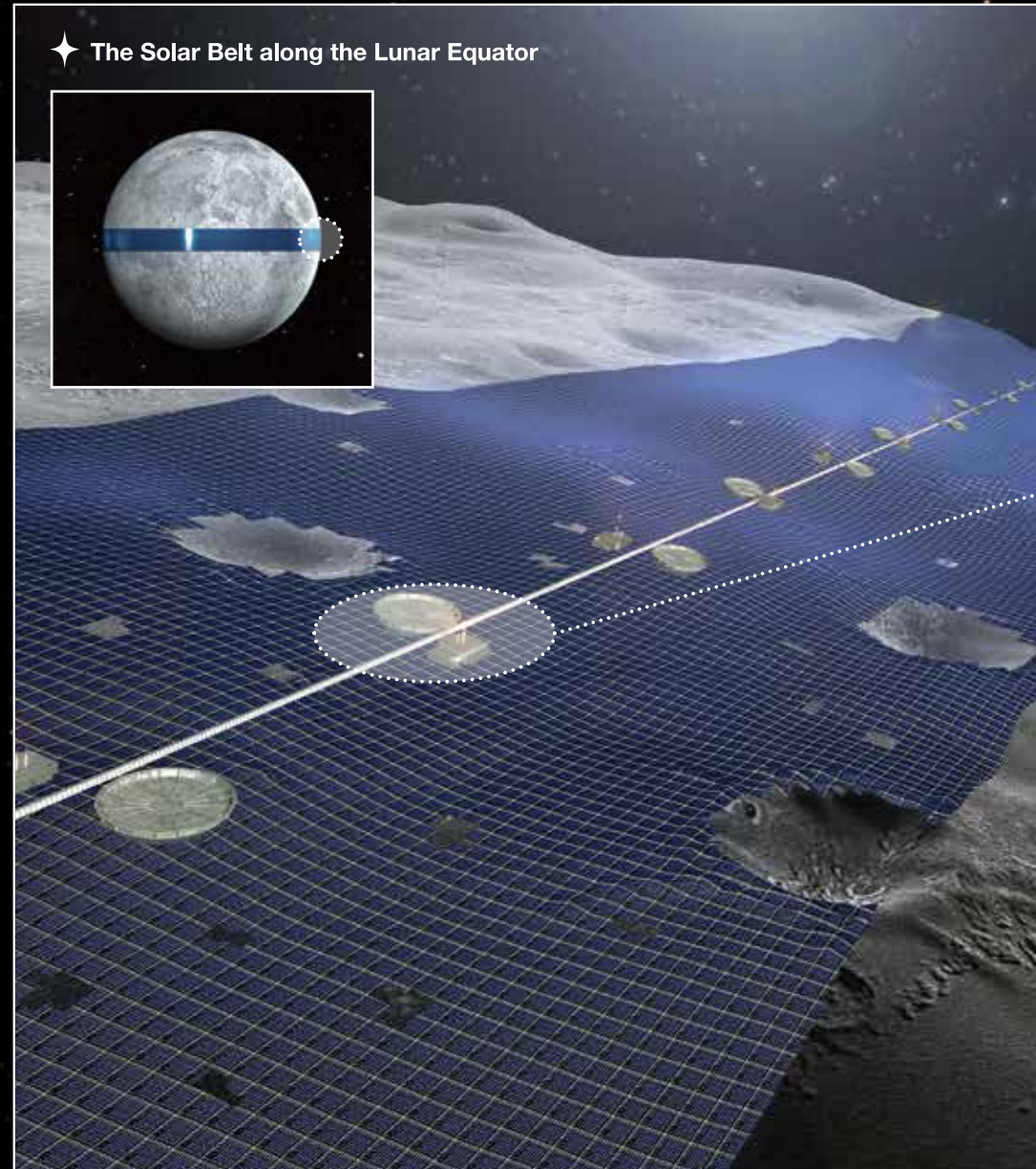
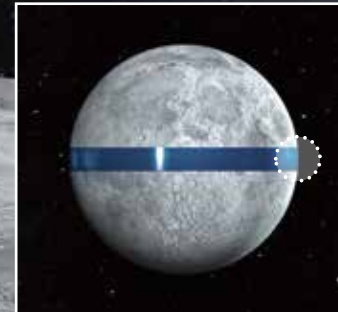


Source: NASA

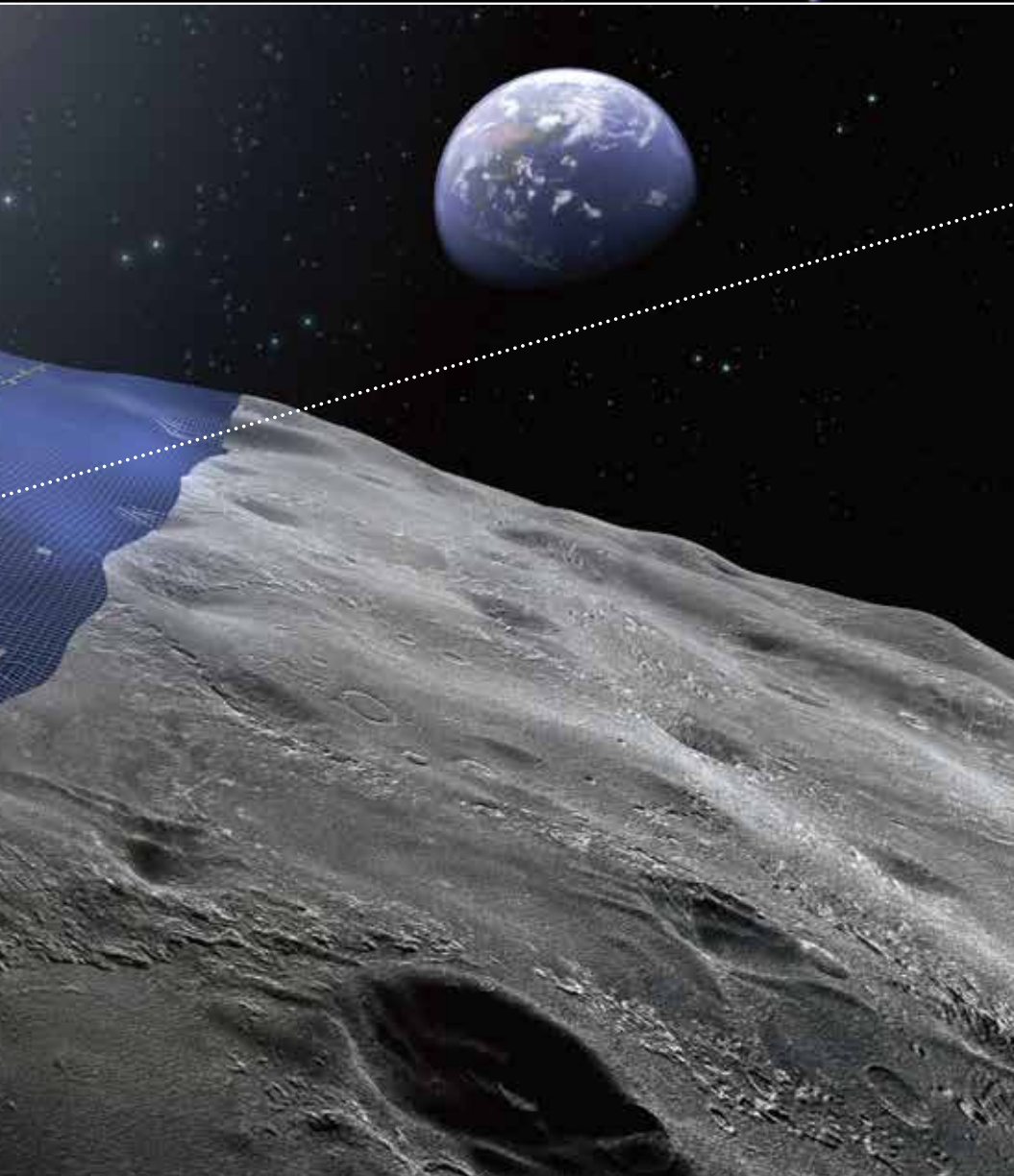
● Work on the lunar surface

A team of astronauts will support robotic surface operation on site.

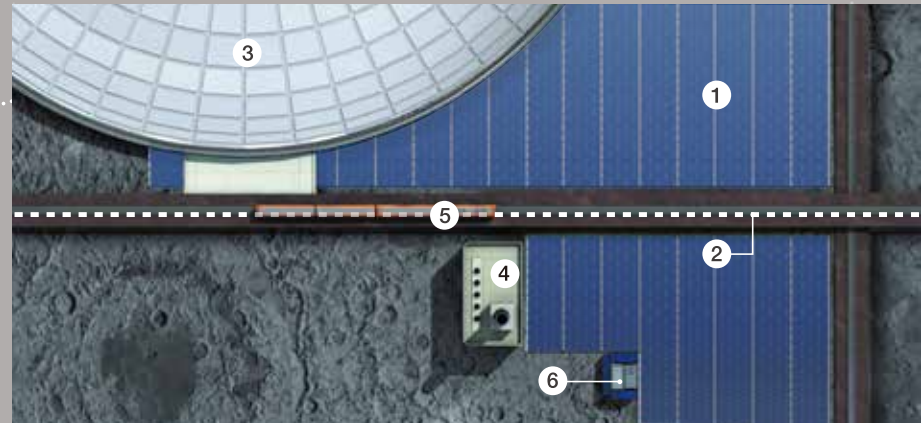
✦ The Solar Belt along the Lunar Equator



solar power plant-



★ The Solar Belt Configuration



1 Lunar solar cells

To ensure continuous generation of power, an array of solar cells will extend like a belt along the entire 11,000km lunar equator. This belt will grow in width from a few kilometers to 400km.

2 Electric power cables

The cables will transfer the electric power from the lunar solar cells to the transmission facilities.

3 Microwave power transmission antennas

The 20km-diameter antennas will transmit power to the receiving rectennas. A guidance beacon (radio beacon) brought from the Earth will be used to ensure accurate transmission.

4 Laser power transmission facilities

High-energy-density laser will be beamed to the receiving facilities. A guidance beacon (radio beacon) brought from the Earth will be used to ensure accurate transmission.

5 Transportation route along the lunar equator

Materials needed for the construction and maintenance of the Solar Belt will be transported along this route. Electric power cables will be installed under the transportation route.

6 Solar cell production plants

The plants will move automatically while producing solar cells from lunar resources and installing them.

Space Technology: the Driving Force for the Prosperity of Man

Space Solar Power

1960s - 1980s

1968

Dr. Peter Glaser of the United States proposes SSPS.¹



Source: National Space Society (NSS)

1977-1980

NASA studies SSPS as a solution to the oil shock problem.



Source: NASA

Early 1990s

1992: Kyoto University successfully flies a model plane using microwave power transmission.

1993: Kyoto University conducts microwave power transmission experiments in space.

Late 1990s

The United States resumes research on SSPS (Sun Tower concept is shown below).



Source: NASA

1990s

1998

The former National Space Development Agency of Japan (NASDA), now the Japanese Aerospace Exploration Agency (JAXA), begins SSPS research.

1999

SSPS research begins in Europe.



Source: European Space Agency (ESA)

Shimizu Space R&D

(Names in parentheses are of contracting organizations.)



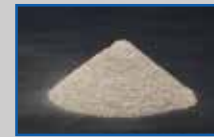
Lunar base made of lunar concrete



Space hotel concept



Construction material production experiments



Lunar soil simulant

Conceptual space systems development

Collaborative international research

Development

- 1987** Shimizu begins space studies by establishing the Space Project Office
- 1988** Development of concept for lunar base made of lunar concrete
- 1989**
 - Space hotel concept development
 - Collaborative research on space robotics with Carnegie Mellon University
 - Collaborative research on space vegetable production technologies with Tokyo University
- 1990**
 - Collaborative research on space robotics with Carnegie Douglas Space Systems Company
 - Production of construction materials from lunar soil
 - Collaborative research on space habitation with Martin Marietta Corporation
- 1991**
 - Collaborative research on lunar surface bases with McDonnell Carbotek, Inc.
 - Successful extraction of water from lunar soil from the Apollo program
 - Lunar surface gravity experiments using parabolic flights on NASA-owned aircraft
- 1992**
 - Collaborative research on lunar concrete technologies with General Dynamics Corporation
- 1993**
 - Space truss assembly and equipment production experiments using the robot system on the ETS-VII (Engineering Test Satellite No. 7, former NASDA)
- 1994**
 - Collaborative research on solar power satellites with University
- 1995**
 - Research on and development of lunar probe mechanisms (former NASDA)
- 1998**
 - Development of lunar probe mechanisms
 - Manufacture of a testing facility for lunar surface activities
- 1999**
 - Ohmsha, Ltd. publishes book that program and Japanese initiatives, ni shigotoba wo tsukuru
- 2000**
 - Research on lunar

1960s - 1980s: U.S.-Soviet space race

1990s: Scientific probes

1969

USA's Apollo-11 makes manned moon landing.



Source: NASA

1970

Former USSR's unmanned Luna-16 collects samples from the Moon and returns them to Earth.

1990

Japan's Hiten orbits the Moon.

1994

USA's Clementine photographs the Moon.

1998

USA's Lunar Prospector observes the Moon's polar areas.

2003

Europe's SMART-1 orbits the Moon.

Lunar Exploration

kind in the 21st Century

-The steps toward The LUNA RING-

2000s

2003

The Space Energy Utilization Promotion Group of House Members is formed by the Japanese government to promote SSPS development.

Laser power transmission experiments begin at JAXA's Kakuda Space Center.



SPRITZ

2004

U.S. President Bush includes SSPS in his new vision for manned space exploration.



Source: NASA

2008

Joint U.S.-Japan microwave power transmission experiments are conducted in Maui, Hawaii.



Lunar resort concept

Future Phases to be Promoted through Global Cooperation

2010s

Experiments and technology development to initiate SSPS and The LUNA RING

- Electric power transmission experiments using satellites
- Solar Bird plan²
- Large-scale space structures and assembly robots in orbit



2020s

Pilot demonstrations on the Earth and the lunar surface

- Demonstration of transmission from geosynchronous SSPS to Earth
- Demonstration of transmission from lunar orbiting SSPS to bases on the lunar surface



2030s

Commercialization of SSPS and preparation for The LUNA RING construction

- Placement of 1GW class commercial SSPS in geosynchronous orbit
- Construction of permanent lunar orbiting SSPS to supply electric power for activities on the lunar surface



Source: JAXA

of lunar surface technologies

2001

• Development of equipment for test drives of lunar rovers
• Development of combined solar cell/microwave power transmission system SPRITZ (JAXA, Kyoto University)
surface excavation discusses the Apollo Tsukie, Iutatabi, Tsuki

2004

• Development of tools for assessing lunar ground characteristics

2005

• Study on economics development of lunar rovers Engineering, Inc. (NASA)
• Development of different lunar soil simulants for different regions of the Moon

2007

• Study on systems for lunar ground exploration
• Support in utilization of data collected by lunar orbiting spacecraft Kaguya
• Study of lunar surface engineering systems

2008

• Lunar resort concept: a commercial facility on the Moon using infatatable space structures

- Lunar exploration robot
- In-situ resource utilization on lunar surface
- Lunar construction system



Source: Carnegie Mellon University

- Mining of lunar surface resources and materials production
- Demonstration plant for lunar solar power generation system
- Demonstrations of lunar construction robots on the lunar surface and tele-operation from the Earth



Source: NASA

2035

The LUNA RING Luna solar power generation project construction begins

- Development of technologies for producing solar cells from lunar resources
- Detailed survey of the entire lunar equator
- Basic design, construction planning and construction simulation for The LUNA RING

2000s: Competition in lunar probes

2007

Japan's Kaguya observes the lunar surface, gravity, etc.

China's Chang'e-1 observes lunar terrain.

2008

India's Chandrayaan-1 conducts scientific exploration of the Moon.

2009

USA's Lunar Reconnaissance Orbiter is scheduled to make detailed lunar maps and research lunar ice.

- Construction of international base for exploration of the Moon's polar area
- Exploration of lunar resources and resource production experiments using robots



Source: NASA

- Construction, expansion and full-time operation of international lunar base
- Development of lunar resource maps
- Development of technologies on processing lunar soil for materials production



- Establishment and execution of the international regime for the lunar solar energy development

Notes: 1. Space Solar Power Systems (SSPS): Systems that gather sunlight in space, generate electricity and transmit energy to the Earth in forms including microwaves

2. Solar Bird plan: A plan in which a uniform array of distributed SSPS transmits microwave power to the Earth, eliminating the need for batteries in mobile phones and other devices



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Today's Work, Tomorrow's Heritage