RESEARCH INTRODUCTION

A day when large artificial satellites solve our energy challenges

Eco-friendly energy supply systems

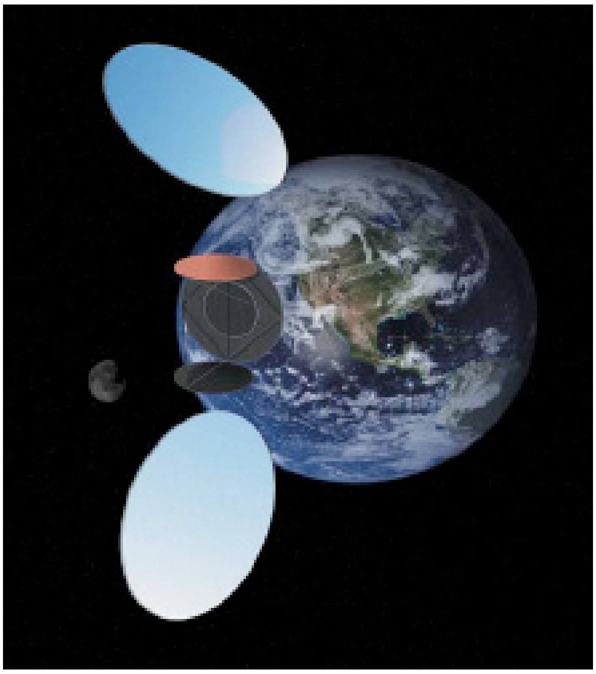
A very large artificial satellite floating in geostationary orbit at an altitude of 36,000 kilometers. The artificial satellite sends energy to the ground without interruption. This is a new energy supply system called the Space Solar Power System (SSPS). JAXA is researching and developing SSPS with plans to construct them in 2030.

The SSPS is environmentally friendly, as it emits no carbon dioxide (CO_2) or other potential contributors to global warming. Some people may associate environmental friendliness with solar cells. A solar cell is an effective, eco-friendly system that can be installed on top of a building or the roof of a house. But the solar cell cannot generate power on the ground on a cloudy day, or when deprived of sunlight during the night. An SSPS can generate power at any time in any weather (except, of course, during an ecliptic period).

SSPS studied by JAXA

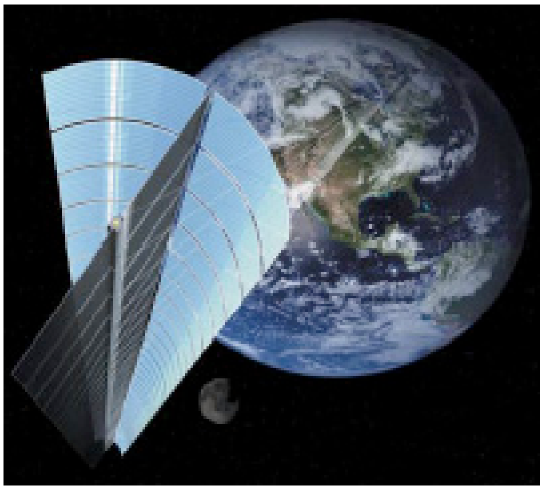
JAXA is studying the development of an SSPS capable of supplying 1 million kW of electricity, the equivalent of the electric power generated by a nuclear power plant. Two system components are required to achieve this: an artificial satellite to collect sunlight in geostationary orbit and send it to the ground, and ground facilities to receive the energy sent from the satellite.

JAXA wants to convert collected sunlight into microwave or laser energy, to send it to the ground. A microwave and laser are electromagnetic waves, each with a different wavelength (refer to here) The properties of electromagnetic waves differ from one wavelength to another. Though microwaves can carry energy to the ground without being affected by cloud, the equipment to send and receive the energy must be of a reasonable size, regardless of the amount of energy handled (Figure 1). For carrying laser, the opposite conditions hold: the size of



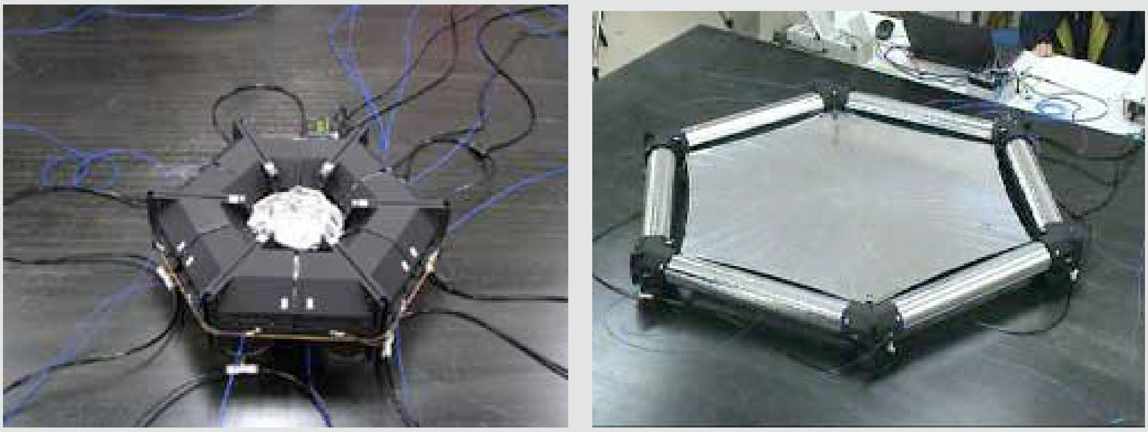
This SSPS collects sunlight into solar batteries. using two huge elliptical reflectors (mirrors), each with a major axis of 3,500 meters and a minor axis of 2,500 meters. Once these batteries generate electricity, the electric power is converted into microwave energy and carried to the ground. The microwave energy is reconverted into electricity with an antenna provided with a rectification function, a so-called rectenna, arranged in an area of a diameter of 2,000 meters. Finally, the electricity is sent to the commercial power grid.

Fig.1 Microwave SSPS (M-SSPS)



The L-SSPS has a basic unit consisting of a condenser, a laser oscillator, and a radiator arranged lengthwise. The system is very efficient, as the sunlight collected into the condenser is converted directly into laser energy by the laser oscillator and sent to the ground. JAXA wants to convert laser energy into electricity and use it to produce hydrogen, a fuel for fuel cells.

Fig.2 Laser-SSPS (L-SSPS)



Before opening　　After opening

Fig.3 Opening of the inflatable structure

the equipment can be scaled up or down according to the amount of energy handled, but a cloud covering is likely to influence the carriage of the laser to the ground (Figure 2).

To construct the SSPS, much remains to be done. It will be important, for example, to find methods for carrying energy to the ground with high efficiency, and for dissipating loss of the heat generated by the collected sunlight. Methods to construct the SSPS will be another big challenge, as artificial structures so large have never been assembled in space.

Assembling the gigantic structure

The largest structure in space is the International Space Station (ISS), now orbiting Earth at an altitude of 400 kilometers. When the ISS is completed, it will be almost as large as a soccer stadium (About 108.5 m x 72 m). The efficient construction of the SSPS, a structure much larger than the ISS, will demand ingenuity.

Under current plans, the SSPS would be taken into space by rocket. Given the limits in payload capacity, only so many fairings can be launched at one time. It will thus be necessary to fold the fairings into small sizes and open them out once in space. The Engineering Test Satellite VIII (ETS-VIII.) launched in December 2006 has two large antennas made of a braided metal. Each was folded up into smaller sizes in the fairing, like a folding umbrella, and later set up in space. Another ingenious idea is an inflatable structure (Figure 3) which fills with injected air to extend its shape. Another is a "furosiki (wrapping cloth)" structure that opens up under centrifugal force. Most of these structures are still in the research phase. JAXA is collecting basic data to determine which structure is the most suitable to the SSPS.

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Space Debris Unit

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RESEARCH INTRODUCTION

Looks unattached, but actually not

With a larger telescope we will see more things

What is dark matter? Do gravitational waves really exist? What is the mechanism of a black hole? Countless mysteries in the universe remain locked. Many of them can be solved with observation equipment more accurate than the equipment we use today.

With larger observation equipment we can observe with higher accuracy. Let's take an optical telescope as an example. As the distance grows between the lens that concentrates the light coming from space and the camera (light-receiving unit) that receives the concentrated light, the resolution of the images grows commensurately. But a single structure incorporating both a lens and camera would be almost too gigantic to build or launch. This is why we turn to Formation Flying (FF) technology as an alternative. Two artificial satellites flying in formation, at a fixed distance from each other, can serve the respective functions of the lens and light-receiving unit. Through this approach, we can commission a gigantic telescope without building or launching a gigantic structure.

A gigantic telescope requires extremely advanced control technology

In 1997, JAXA launched the Engineering Test Satellite VII (ETS-VII), an observation telescope consisting of two satellites, the "Orihime (Vega)" and "Hikoboshi (Altair)." The next year, in 1998, the agency carried out a rendezvous and docking experiment (on July, 7 the day of the Tanabata Festival). In this experiment, these two satellites successfully demonstrated FF technologies by flying in formation, maintaining their formation positions with high accuracy, safely taking shelter from unusual events, and returning to their original positions after taking shelter. Though these technologies demonstrated in 1998 are still the world's most advanced, we will need maintain the formation positions with much higher accuracy before we can execute the advanced missions envisioned for the future (Fig.1).

To accurately control the relative positions, we need extreme precision in the control of the thruster propulsion system and the "relative navigation sensor," the device to measure the satellite positions with respect to each other. The accuracy of the relative navigation sensor is the most important challenge of all. JAXA is trying to increase the measuring accuracy by an order of magnitude by developing an image navigation sensor for FF (FINE) (Fig.2) based on the sensor technology obtained through the development of the ETS-VII. Tests have already proved that the target accuracy can be attained.

The ETS-VII has achieved 1-centimeter control accuracy for a relative distance of one meter. In various planned missions, 1-centimeter control accuracy will be required for a relative distance of several hundred meters. To succeed in this, JAXA

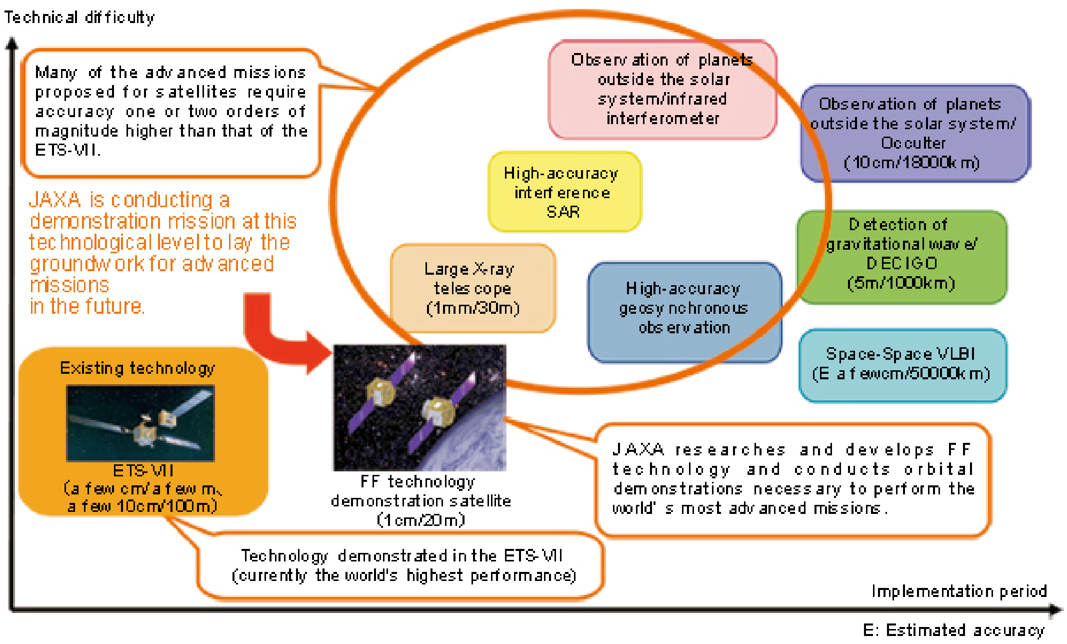
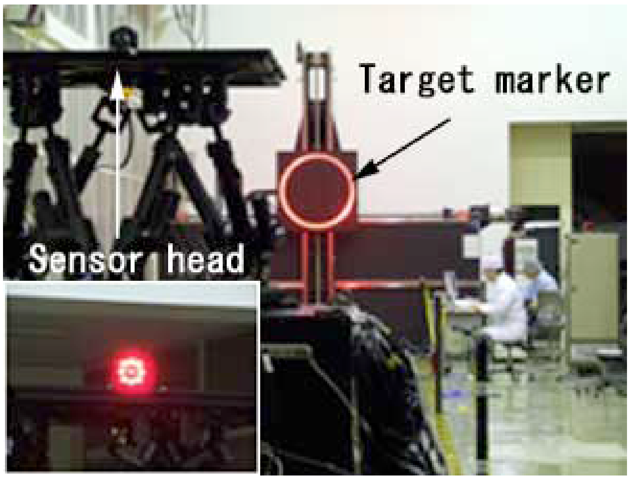


Fig.1 Formation position control accuracy between ETS-VII and future required missions



The master satellite is equipped with a light-emitting sensor head and the slave satellite is fitted with an elliptical target marker to reflect the light from the sensor head. The light reflected by the target marker is captured by a camera mounted on the sensor head to determine the position (up and down, right and left, back and forth) based on how the circle of light is seen.

Fig.2 Scene from the development test for the image navigation sensor for FF (FINE: Formation flight Image Navigation Equipment) by RDOTS

is actively promoting research and development to achieve control accuracy of an order of magnitude higher within the next five years.

JAXA seeks to demonstrate a X-ray telescope system in space using small satellites

Osaka University and other organizations are preparing for the demonstration of an X-ray(*1) telescope system with FF technology in what they call the FFAST project (Figure 3). JAXA is participating in the project as a collaborative research institute in two ways. First, it is conducting agency tests of various equipment prototypes, including the FINE.

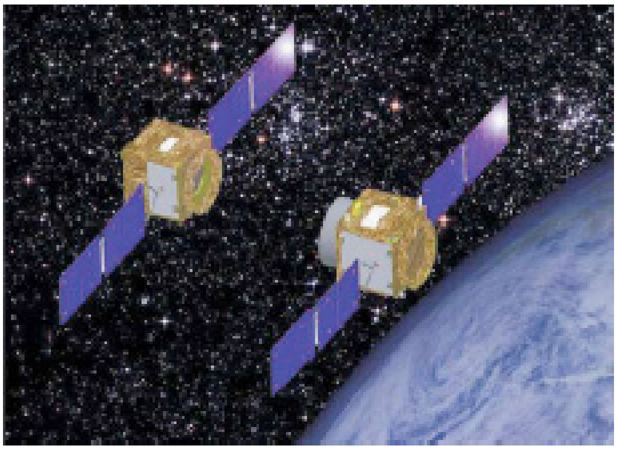
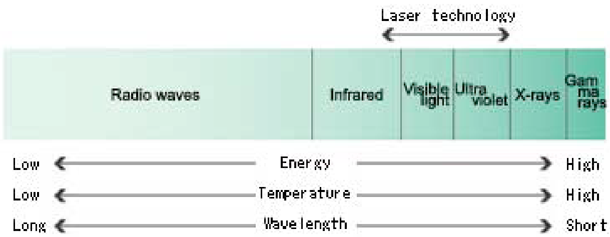


Fig.3 FFAST project (supplied by NEC)

Second, it is developing an FF simulation system which combines the control systems necessary for FF technology.

(*1) X ray : X-ray is a kind of electromagnetic wave (radiation). The energy of an electromagnetic wave varies as the wavelength changes. Energy is closely related to the temperature of the electromagnetic radiation. As the temperature rises, the electromagnetic wave emits higher-energy light. With an X-ray telescope, we can see black holes and celestial objects that emit higher-temperature light than visible light



Laser: Light amplification by stimulated emission of radiation

[Guidance and control Group]

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