

Colleagues are Robots

Robots are required to play an active role in space

Space development and utilization are becoming more and more active. Most of those activities are currently supported by astronauts. However, since astronauts are human and not robots, astronauts cannot work 24 hours a day. They have to take sleep, rest, foods and their own private time. Therefore, even though the number of astronauts on the international space station is at most seven, number of working astronauts at any timing except in case of emergency, is only two. Another two astronauts are sleeping and remaining astronauts are taking rest or food. Therefore, in order to utilize the space station, utilization of robots will be important.

We are developing an astronaut support robot (Astrobot = Astronaut + robot). The astrobot should be able to move to a worksite on the large space facility such as the space station and the space solar power satellite (SSPS). the Space Solar Power System (SSPS) in a geosynchronous orbit at an altitude of 36,000 km.

Dexterous hands and interesting feet

Nawadays, various types of robotic hands are being developed for the on-ground applications. Capability of

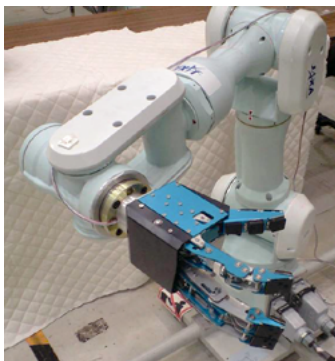
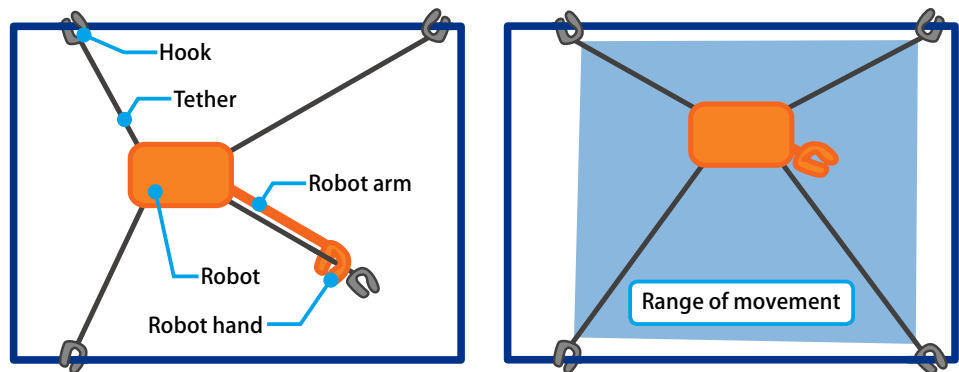


Fig.1 Robotic hand that was developed

these robotic hands are mostly limited. The hands of humanoid robots have a shape similar to that of a human hand; however, they generally have weak grasping power and can only grasp light objects. Considering that the robot is to support or perform the work of astronauts, a robotic hand for the astronaut support robot should be same size as a spacesuit glove and has the grasping force equibarent with an average adult and is able to hold and operate tools used by astronauts. Such a robotic hand was developed in collaboration with THK Co., Ltd. and Keio University. (Fig. 1) This hand can be attached and removed from the arm, allowing a proper type of robotic hand to be exchanged according to the job being performed.

The astronaut support robot shall be able to move around the workplace. Several locomotion method for the space robots were considered. However existing locomotion methods need fuel or complicated infrastructure to realize the locomotion. Therefore, we are thinking a Spider-Man-like robot, which "moves using tethers". The robot has an extendable arm and multiple tethers, each with a hook at the end. The robot arm is operated to stretch the tethers and hook them onto surrounding structures. (Fig. 2a) With three or more tethers secured, controlling the length of the tethers allows the robot to be moved within a plane or polyhedron with each



- a The tether is gripped by the robot hand, the arm is extended, and the hook at the end of the tether is secured to a surrounding structure.
- b By stretching or shortening the tether, the robot can move within a plane or polyhedron with the hooks as vertices.

Fig.2 Concept of robot movement using tethers

Research and development of astronaut support robots

hook (fixed point) as a vertex. (Fig. 2b) By changing the position where the hook is secured, the robot's range of movement can be changed autonomously..

The extendable robot arm becomes cylindrical by curving and layering two long sheets. (Fig. 3) When stored, the sheets are rolled up, like a tape measure, and are extended and retracted by a motor during operation. The material, carbon fiber-reinforced plastic (CFRP), has a low thermal expansion and is light and durable, compared with metal. The end of the arm is equipped with a hand and a monitoring camera, which is used to measure the distance to an object when operations are performed. .

Technological experiment REXJ

In January 2012, with the aim of demonstrating the spatial locomotion technology of the Astrobot, the technological experiment REXJ (Robot Experiment on JEM-KIBO) will be conducted using the Japanese experiment module "Kibo" on the ISS. (Fig. 4)

"Kibo" is a Japanese experiment module comprising the pressurized module and the exposed facility. REXJ will be conducted in an experiment payload installed on the exposed facility. In order to gain an understanding of the operating properties of the extendable robot arm, the hooks at the ends of the tethers will be secured and the robot arm will be moved along the same hand rails used by

astronauts during extravehicular activities. We will also control the length of the tethers to move the robot in order to confirm that it moves without vibrations so that we can gain an understanding of spatial locomotion properties. Furthermore, we plan to stretch the extendable robot arm from a window of the module out into space for outside observation and to conduct assessment testing of the robot arm exposed to the thermal environment of space.

Construction of the ground operating system is currently progressing.

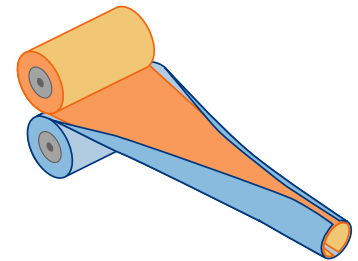


Fig.3 Image of robot arm extension

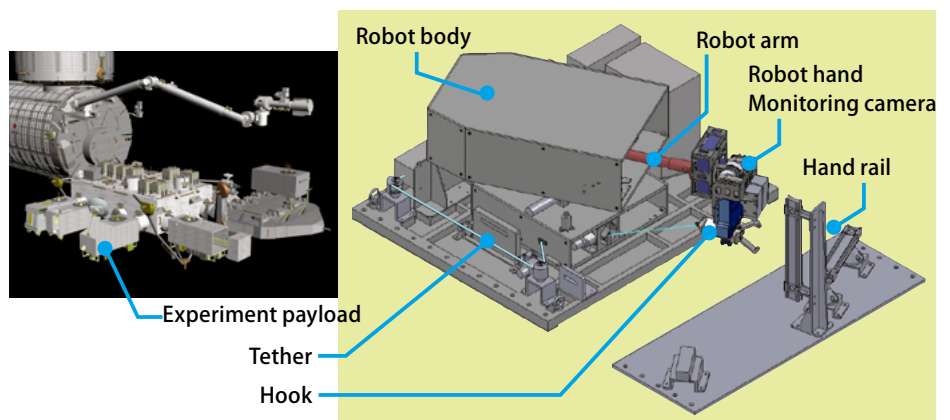
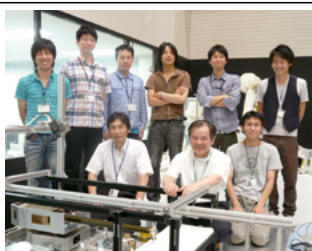


Fig.4 Exposed facility of "Kibo" (left), REXJ robot (right)



[Innovative Technology Research Center]
Robotics Research Group

REXJ development team members of Aerospace Research and Development Directorate
(Front center) Mitsushige Oda

Looking for a tool to see space in detail

Making a lightweight large mirror

Many "observation satellites" have been launched into Earth's orbit in order to capture the birth of galaxies and their evolution process. The observation accuracy of a satellite is determined by various factors; and, the "aperture" (diameter of the primary mirror) of telescopes installed on satellites observing the visible and the infrared ranges is essential. A larger aperture can gather more light and increase the "resolution" allowing faint stars to be observed in detail. Since man-made satellites are launched into space defying gravity, there are limitations on weight. When a large telescope aperture is desired, it is more efficient for the primary mirror, which determines the size of the aperture, to be lighter.

The primary mirrors of optical telescopes have been made of glass with low temperature deformations, called "low thermal expansion glass". However, its mass is so heavy that the primary mirror for the Hubble Space Telescope (USA), launched in 1990, has a mass of 830 kg with a diameter of 2.4 m. Recently, a lighter weight was achieved by making a primary mirror of silicon carbide (SiC), like that in the infrared imaging satellite Akari (Japan), launched in 2006. (Fig. 1)

With the aim of making lighter and more accurate

telescopes, we have set our sights on carbon fiber-reinforced plastics (CFRP). Advantages of CFRP for telescope mirror are ultra-lightweight, high elastic modulus, and easy to fabricate large scale structures. It also possesses such characteristics as extremely high dimension stability. (Fig. 1, Fig. 2)

Overcoming unevenness of fibers

CFRP are formed by stacking sheets, called "prepreg", which are carbon fibers aligned in the same direction and impregnated with resin, into a number of layers, then cured. CFRP are used, for example, in satellite structures. Although the weight of satellite structures has been achieved to be lighter with a sandwich construction, where a core with a honeycomb configuration (hexagons arranged like in a beehive) is inserted between two sheets, CFRP are contributing to even lighter satellite structures. (Fig.3a)

The surface of CFRP appears smooth; however, the unevenness between the fibers and resin can be seen in closeup view. (Fig.3b) Since the roughness of a surface becomes larger relative to the wavelength of the light used to observe, accurate observation is impossible. We believe that a good method for reducing surface roughness would be to apply a thin coating of resin over the surface. Figure 4

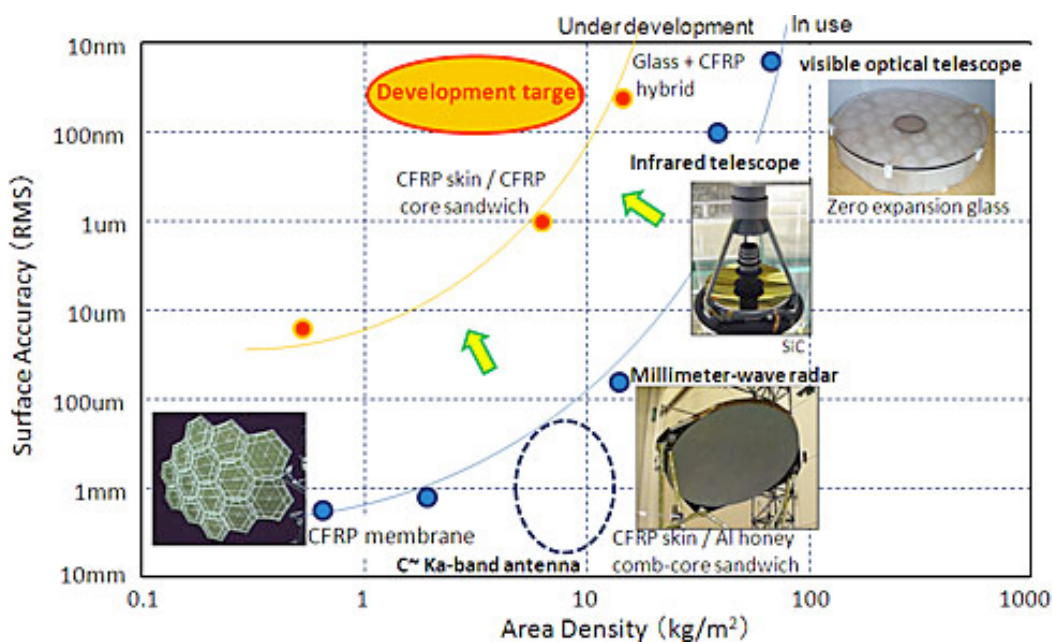


Fig.1 Area density and mirror accuracy of primary mirrors depending on material

Research on a CFRP mirror for improved observation performance

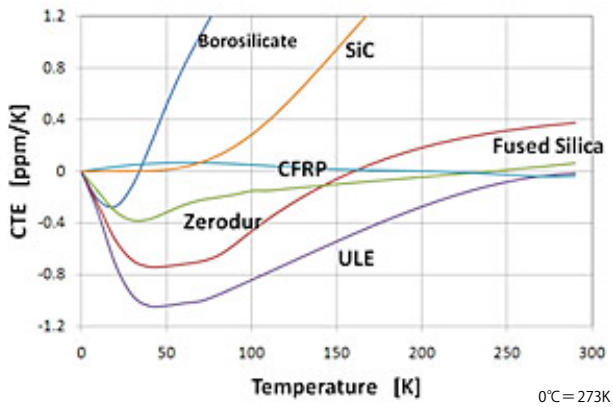


Fig.2 Coefficient of thermal expansion for various materials for telescope

shows a prototype of this CFRP mirror. Compared with the mirror on the right, we can see that the mirror on the left, which has been properly coated with a resin layer, reflects light with greater accuracy.

Understanding moisture deformation

We previously mentioned that CFRP have a low thermal expansion. (Fig. 2) However, they have the disadvantage that deformation occurs when moisture is absorbed

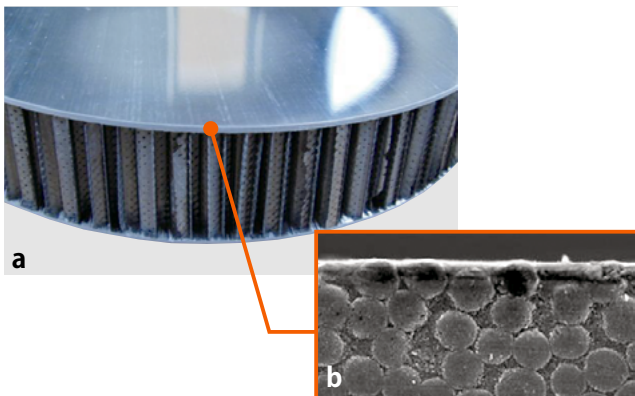


Fig.3 CFRP satellite structure (a) and closeup view of CFRP surface (b)

(moisture absorption deformation). Although moisture absorption deformation is a problem on Earth, the issue becomes the deformation that occurs when the stored moisture escapes after launched into the vacuum of space (moisture desorption deformation). We could maintain the necessary mirror accuracy if we can gain an understanding of how a CFRP mirror is deformed as a result of moisture desorption deformation and create a design that takes this degree of deformation into account. Since CFRP are also used in the optical table where the telescope is installed, assessment of moisture absorption and moisture desorption deformation would greatly contribute to improving observation accuracy.

In the future, we will continue to further improve mirror accuracy and assess moisture absorption deformation with the aim of establishing technology to create a large mirror in the 3-meter class.



Compared with the conventional product on the right, the roughness has been suppressed in the CFRP mirror on the left, which had been properly coated with resin, allowing the text to be reflected more clearly.

*In order to maintain its function as a mirror, aluminum has been deposited on the surface.

Fig.4 Prototype of CFRP mirror



[Spacecraft Structures and Mechanisms Group]

(From left) Yamawaki Toshihiko, Mizutani Tadahito, Yasuda Susumu, Utsunomiya Shin, Kamiya Tomohiro, Shimizu Ryuzo

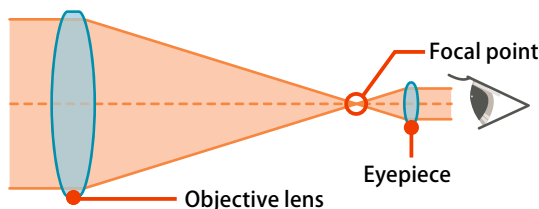
Telescopes – Equipment to learn more about space

Types of astronomical telescopes

In Japan, Fall brings to mind the moon-viewing festival Otsukimi. This year, this celebration of the full moon falls on September 22nd. The round moon reflects the sunlight and shines like a Japanese rice dumpling.

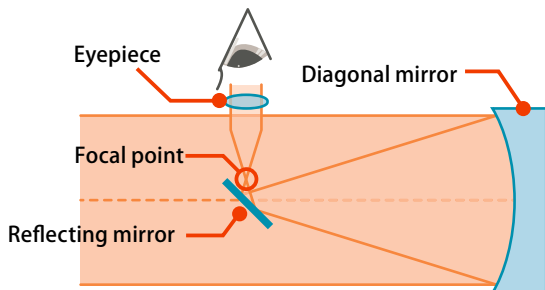
The surface of the moon is covered with geographical features of various sizes, called craters and seas, which were formed by meteorite impacts. In order to see these features in detail, observation using an astronomical telescope is advised. An astronomical telescope is a device that allows distant stars to be observed in detail through a construction of lenses and mirrors. It consists of an "objective lens (or mirror)", which condenses light, and an "eyepiece", which, acting like a magnifying glass, magnifies the collected light. There are two types of astronomical telescopes according to their method of capturing the light: "refracting" and "reflecting". (Fig. 1, Fig. 2)

Astronomical observation by various types of



Light is collected by the objective lens to create a focal point, and then that point is enlarged by the eyepiece.

Fig.1 Basic principle of refracting telescopes



Light is collected by the reflecting mirror to create a focal point, and then that point is enlarged by the eyepiece. Light reflected by the reflecting mirror is bent by the "diagonal mirror" to the outside of the body, where it is viewed.

Fig.2 Basic principle of reflecting telescopes

light

There are various types of light. "Visible light" is light that can be perceived by our eyes. There are also radio waves (which are used to send radio and television signals), infrared rays (which are used in heaters to generate heat), ultraviolet rays (which cause skin to tan), and X-rays (which are used to take an X-ray picture). These are collectively called "electromagnetic waves". (Fig. 3) Generally, substances give off electromagnetic waves according to the temperature and energy state. Radio waves, which are low-energy electromagnetic waves, radiate from places with extremely low temperatures such as space or, for example, places where gas or dust has accumulated. Conversely, high-energy electromagnetic waves, especially X-rays, radiate from places with intense activity such as at the center of a galaxy or in regions extremely near black holes. As with visible light, any electromagnetic wave is first collected to a point with

a condenser, then directed at a detector with a method appropriate for the wavelength.

In observations of radio waves, which have longer wavelengths than visible light or infrared rays, darker astronomical objects can be observed when more light is collected with a larger aperture. In addition, the "resolution", which allows more detailed parts of astronomical objects to be observed, will also increase. Therefore, we continue to make larger telescopes for research, such as the optical infrared telescope "Subaru" with a diameter of 8.2 m, one of the largest in the world, which was constructed in Hawaii by the National Astronomical Observatory of Japan. The surface of the mirror requires a smoothness (mirror accuracy) of 1/10 to 1/20 the wavelength of the electromagnetic wave being observed. Since the mirror surface becomes distorted by its own weight due

to the large diameter, computer-controlled devices have been designed to reduce the distortion. Since the resolution becomes coarse proportionally to the wavelength, an especially large diameter is required for radio waves, as compared with other electromagnetic waves. In Puerto Rico, the world's largest single-aperture radio telescope, with a diameter of 305 m, has been constructed in a natural depression.

Radio waves can be observed with a radio interferometer, which uses telescopes (parabolic antennas) installed at intervals. By using multiple parabolic antennas, we are able to view at the same resolution as a single telescope with a diameter equivalent to the largest spacing between two antennas. With the aim of being fully functional by 2012, we are currently continuing with the construction of the "Atacama Large Millimeter Array" (ALMA), which comprises 80 parabolic antennas, in the Atacama desert (Chile) in collaboration between Japan, Taiwan, United States, Canada and Europe.

■ Telescopes launched into space

Earth is a planet enveloped by an atmosphere. We can live thanks to this atmosphere. However, the atmosphere also interferes with the various electromagnetic waves reaching the ground.

In order to observe without interruption from Earth's atmosphere, the method of launching telescopes into space and observing from there is being adopted. A well-known example is the Hubble Space Telescope, launched by the United States in 1990. The Hubble Space Telescope is an enormous space observatory

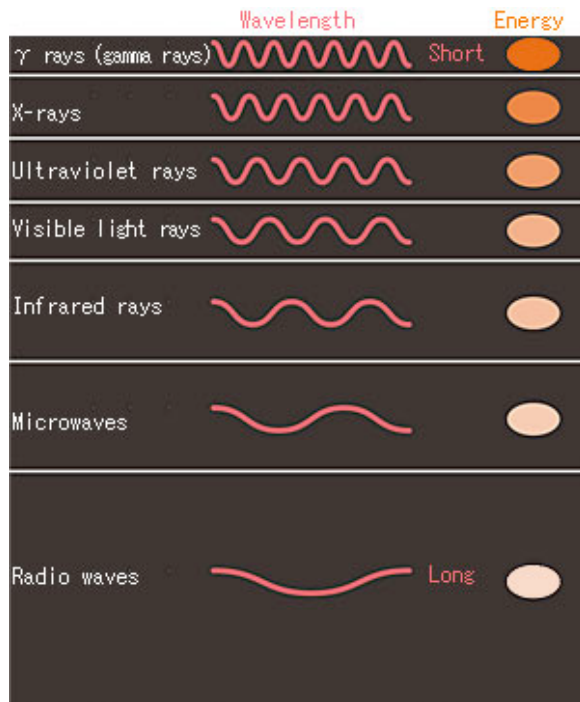
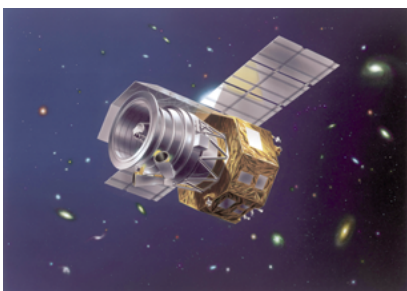


Fig.3 Types of electromagnetic waves

with a 2.4 m primary mirror. It is equipped with a camera that can observe visible light as well as infrared and ultraviolet light.

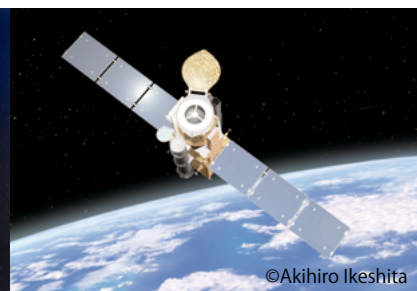
JAXA is also launching various space telescopes. The infrared imaging satellite "Akari", which is mapping space in infrared, the large-size X-ray astronomy satellite "Suzaku" with a total length of 6.5 m, as well as the solar observation satellite "Hinode" continue to provide excellent research results.



Infrared imaging satellite "Akari"



X-ray astronomy satellite "Suzaku"



Solar observation satellite "Hinode"