JAXA's Space Robotics Road Map

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Abstract

The Japan Aerospace Exploration Agency (JAXA) presented its vision for Japan's future space activities in April 2005. This vision includes (1) realization of a safe and comfortable life for taxpayers utilizing aerospace technology, (2) exploration of the Moon and the solar system, and (3) the capability to conduct autonomous space activities. Space robotics is being considered as a key technology to realize these goals, and a space robot task force has been organized to provide a strategy for developing and utilizing space robotics to realize the goals of the vision. This paper introduces the intermediate results produced by the team.

1. Introduction

Japan began its space activities some 50 years ago by launching the "Pencil Rockets" (1955). Japan's first satellite, "OHSUMI," was launched in 1970. Since then, Japan has launched more than 80 satellites. Japan's main launch vehicle, H-IIA rockets were successfully launched 13 times since 2001. JAXA employs 8 astronauts. Japan's experiment module for the international space station (JEM) will be launched in 2008.

Based on these successful experiences, the Japan Aerospace Exploration Agency (JAXA) proposed its vision for Japan's future space activities in April 2005. This vision (JAXA2025) proposes several goals to be achieved over 20 to 30 years. The proposed goals are as follows.

* Contribute to sustaining a safe and comfortable daily life for taxpayers using aerospace technology such as environment-monitoring satellites and advanced communication satellites.

* Explore the Moon and solar system to extend the frontiers of our knowledge.

* Strengthen Japan's aerospace technologies.

Since the vision consists only of proposed goals, a further effort to shape the vision into a strategy for realizing the vision is necessary. Therefore, several task forces (study teams) were organized to develop a strategy to realize the vision. One of the newly organized teams is a robot study team charged with developing strategies involving space robots to realize the proposed goals. The space robot study team is one of the newly organized teams within JAXA. It is composed of members from many offices within JAXA.

2. Space Robotics for future missions.

2.1 Definition of space robotics

Through discussion among team members, space robotics is defined as follows.
"Space robotics / Space robots are either tele-operated or autonomous system (or subsystem of a large system) that will have the sensing subsystem to identify robot's working environment and either the manipulation subsystem to manipulate the interested object or the locomotion subsystem to move around the interested area. Task of space robotics / robots is to help succeed a mission." Therefore, space robotics / robots are not a mission by itself. Some people misunderstand such that the space robot can be a mission by itself.

2.2 Areas that the space robotics / robots can contribute

Space robotics / robots can contribute in following mission areas.

* Exploration robotics which will support the exploration missions such as moon or mars exploration rovers, micro-robot to explore small asteroid and construction of moon base
* Manned Space Activity support robots which will support the manned space missions such as an EVA/IVA support robots
* Orbital robotics which will support the satellite missions such as inspection, re-fuelling, maintenance of orbiting satellites, assembly of large satellite.

3. Roadmap of the space robotics in each area

3.1 Moon exploration

Recently, the moon exploration interests the major power in the world where the space development is advanced. In these 10 years, NASA, ESA, Japan and China launched moon orbiting exploration satellites. India and the USA will launch another moon orbiting exploration satellite in the year 2008.

Japan launched a Moon-orbiting satellite named "Kaguya" or SELENE (SELenological and ENgineering Explorer) on September 14th, 2007. KAGUYA was placed in a moon orbit whose height is 100km. KAGUYA carries various instruments to observe moon such as the X-ray Spectrometer, the Gamma Ray Spectrometer, the Multi band Imager, the Terrain Camera, the Laser Altimeter, the Lunar Magnetometer, the Charged Particle Spectrometer and others. KAGUYA is a largest moon orbiting satellite after the Apollo program. Its mass is 3 ton. It also carries the High Definition Television Camera to show the Moon from as near as 100km by the High definition images. Figure 2 shows images of the moon surface taken by the KAGUYA's high definition TV camera.

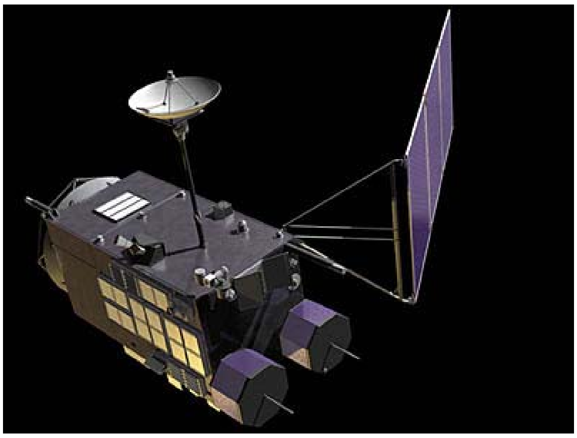

Figure-1 "Kaguya", JAXA's moon orbiting satellite

Figure-2 High Definition TV image taken by "Kaguya"

After successful launch of KAGUYA, Japan is considering launch of KAGUYA follow-on mission. The KAGUYA follow-on mission will include landing on the moon surface and conduction surface exploration by a moon rover. This mission is being considered to be conducted by the mid of next decade.

For the KAGUYA-follow-on mission, various kind of technology research and development are in progress now. Figure-3 shows a test model of the moon rover.

Japan's further strategy to proceed further into the manned moon exploration phase is to be decided around the year 2015 based on these robotic moon exploration results. If Japan does decide to continue its efforts and enter a manned Moon exploration phase, it will want to send Japanese astronauts to the Moon's surface as part of an international exploration crew.. Moon-based facilities will be built to support astronaut activities on the Moon's surface. Figure 4 shows an artist's image of an international Moon base.

Figure-3 A test model of a moon rover

Figure-4. Artist's image of a Moon base.

3.2 Solar system exploration

The Solar system exploration missions can be categorized into two groups. One is for programmatic exploration, which should be conducted periodically. A follow-on robotic exploration mission to a small body, like the Hayabusa mission to the ITOKAWA conducted in 2005, is an example of programmatic exploration.

The other group is for unique, challenging missions conducted to study unvisited small bodies. This kind of mission will not be conducted periodically, but rather will be conducted only when a unique technology or opportunity presents itself. Figure 5 shows an artist's image of HAYABUSA after landing on ITOKAWA. Figure 6 shows a micro-robot probe (MINERVA) mounted on HAYABUSA.

Fig. 5. Artist's image of HAYABUSA on ITOKAWA.

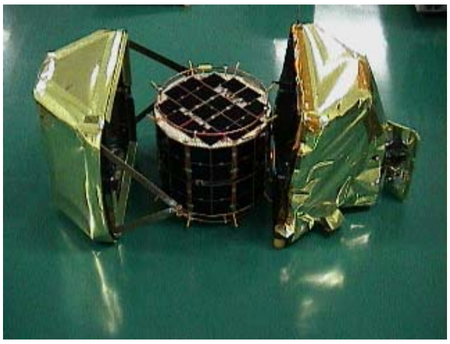

Figure-6. Micro-robot probe MINERVA of the HAYABUSA.

3.3 Manned space activity support robot

This year (2008), the Japanese Experiment Module of the International Space Station (ISS) will be launched. Construction of the ISS will be finished by the end of the year 2010. It is expected that the number of astronauts who stay of the ISS will increase and the manned space activity become full-scale. However, the number of astronauts who stay on the ISS is not enough when we consider the number of laboratory and the number of astronaut on the ISS. Therefore, if a part of the work of the astronaut is executed by robots, it will be very preferable. We'd like to call such robots as the manned space activity support robots.

We interviewed several astronauts to examine necessity of such robot and its functions. Then we learned that several tasks such as bellow should be conducted by robots.

* Handling massive payload
* Capturing orbiting satellite
* Transporting equipments necessary for EVA.
* Inspection of the space station
* Video monitoring of the crew in EVAs.
* Inventory check

Some of these tasks can be conducted by the existing robot system such as the space station remote manipulator system. However some of the above tasks such as transporting equipment for EVAs, and the video monitoring of EVA crews are impossible to conduct by the existing ISS's robot system.

JAXA is to develop the manned space activity support robots and also technological demonstration of the robot on the ISS/JEM.

Japan is to decide whether to proceed into the manned moon explorations or not in the year around 2015. Development and utilization experiences of the manned space activity support robot will be utilized in this decision making.

3.4 Orbital robotics

(1) Satellite servicing

Artificial satellites currently operated in the Earth orbits are mostly disposal type. If a satellite uses all its fuel or loses its major functions, satellite finishes its life. If a satellite can receive its additional fuel in orbit, or can exchange its equipment in bad condition, the satellite can extend its mission life or improve its capability. DARPA conducted an experimental satellite servicing mission by its orbital express satellite in the year 2007. NASDA (former JAXA) also conducted a similar mission in the year 1997 to 1999 using the ETS-VII satellite. The ETS-VII conducted automated rendezvous docking experiments and the tele-operated robot exeriments.

Since number of satellites in orbit is increasing, probability of satellite collision is increasing. In near future de-orbiting from the operation orbit before the satellite finishs its mission will become necessary. If the satellite lost its function before de-orbiting, some kind of de-orbiting service maight becom necessary.

(2) Construction of large space structure or satellite in orbit

Satellites in the Earth orbit, such as LEO and GEO, will be used for Earth observations (land, environment, and weather) as well as for communications and other purposes. The scale of satellites is generally becoming larger and larger. However, since the size and capability of rockets are limited, large satellites will be built up in orbit by assembling several satellite units or by placing several satellites so that each satellite can act as an element of one large virtual satellite. Constellation or formation-flying technologies are used to realize these large virtual satellites.

When we consider further future, construction and maintenance of large satellite and large space platform will be a task of space robot. Continuous earth observation / monitoring from GEO will need large optics which will have to be assembled in orbit. Construction of the space solar power system or the solar power satellite is definitely a task of space robot. When the solar power satellite was studied in 1970's by NASA and DoE, the solar power satellite whose size is 5km by 10km was thought to be assembled by human workers of more than eight hundreds. From the economical and human safety points of views, such a large space facility should be built by robots.

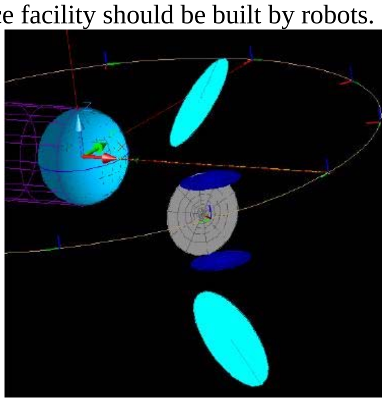

Figure-7 An artist image of the solar powr satellite

Conclusions

This paper has introduced JAXA's strategy for its space robotics.