SCIENTIFIC CAPABILITY OF MINERVA ROVER IN HAYABUSA ASTEROID MISSION.

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Introduction: The Institute of Space and Astronautical Science (ISAS) of Japan has launched the engineering test spacecraft "HAYABUSA" (formerly called "MUSES-C") to the near Earth asteroid "ITOKAWA (1998SF36)" on May 9, 2003 [1]. HAYABUSA will go to the target asteroid after two years' interplanetary cruise and will descend onto the asteroid surface in 2005 to acquire some fragments, which will be brought back to the Earth in 2007.

A tiny rover called "MINERVA" (MIcro/Nano Experimental Robot Vehicle for Asteroid) has been installed on HAYABUSA spacecraft as an in-situ observation component on the asteroid surface (Fig.1) [2]. It will be deployed onto the surface immediately before the spacecraft touches the asteroid to acquire some fragments. After the deployment, it will autonomously move over the surface by hopping for a couple of days and the obtained data on multiple places are transmitted to the Earth via the mother spacecraft while HAYABUSA remains near the asteroid before the departure for the Earth (Fig.2).

MINERVA is the first asteroid rover in the world. It is one of the technical challenges on HAYABUSA mission and its major objectives are as follows.

(1) establishment of mobile system over the microgravity environment of small planetary bodies.

(2) demonstration of fully autonomous exploration capability equipped with the rover.

MINERVA was designed to pursue the technical purposes and has not sufficient scientific sensors to characterize the asteroid surface. But small cameras and thermometers are installed in the rover and scientific contribution is also expected. This paper describes the MINERVA rover and its expected scientific capabilities.

Rover: ITOKAWA is an asteroid newly discovered in 1998. According to the latest observation from the Earth, the shape is approximated to be an ellipsoid with diameters of about 620 × 280 × 260[m]. The gravity on such a small body is on the order of 10 [μG], which is extremely weak compared with that on the Earth. In such a weak gravity, traditional mobilities such as wheeled ones are not fitted because the obtained friction is too small to accelerate the rover horizontally.

The MINERVA rover has the mobility which is specialized in hopping. By rotating a torquer inside the rover, a reaction force against the surface makes it hop[3]. The hop speed is largely dependent on the actuated torque. So it can be roughly controlled onboard, but not so precisely because the hop speed is also affected by the friction between the rover and the surface which can not be predicted. Depending on the friction coefficient, a maximum speed of 9[cm/s] can be attained using the selected torque.

Preflight evaluation of the mobile system was continuously conducted by numerical simulations and microgravity experiments using drop towers[4]. The mobilie system will be finally evaluated by the mission.

Figure 1: Flight model of MINERVA rover

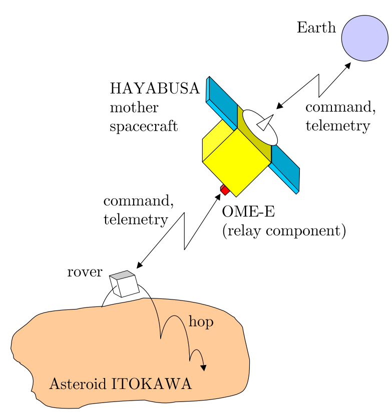

Figure 2: MINERVA mission configuration

Table 1: Rover Specifications

size	hexadecagonal pole (diameter: 120[mm], height: 100[mm])
mass	591[g]
CPU	32bit RISC CPU, clock 10[MHz]
memory	ROM: 512[kB], RAM: 2[MB], Flash ROM: 2[MB]
temperature range	-50 $\sim$ +80 [°C]
hopping ability	9[cm/s] (max)
power supply	solar cells: 2.2[W](max), 1.6[W](min) 1[AU] from the Sun capacitors : 5[V],25[F]
communication	9,600[bps] (communicable distance: 20[km])
sensors	three CCD cameras six thermometers six photo diodes

The acquired data by the rover are transmitted to the Earth via the mother spacecraft. The communication link is very narrow with a long time delay (about 30[min] of round trip) when the rover is on the asteroid. Additionally it is not always established between the rover and the Earth because the Earth-spacecraft communication and the rover-spacecraft one may not be attained simultaneously. Thus, teleoperating the rover from the Earth is not practical and the rover needs the fully autonomous exploration capability, which is demonstrated by the mission[5].

The specifications of the rover is summarized in Table 1.

Onboard Sensors and Expected Science: The rover has three color CCD cameras to capture the surface images and six thermometers to measure the surface temperature.

There are camera windows at the center of the side faces of the rover, through which the cameras view the outside. All the cameras are commercially available and sensitive in visible wavelength. The focal length can not be adjusted onboard. So two of the cameras, which consist of a stereo pair, are set to observe nearby scenes and the last one is for more distant views.

There are pins sticking out from the body to protect the solar cells. Six of the pins are also used as thermal probes, by which the temperature of the surface is measured.

The scientific results expected from the rover are listed below.

- obtain images of the asteroid surface in visible wavelength.
- construct a detailed surface model by comparing a pair of images which is taken by two cameras with short focal length and investigate the presence of surface regolith and ongoing space weathering.
- directly measure the surface temperature.
- investigate the surface thermal properties from temperature history of the same place by disabling the autonomous movement.
- estimate the local gravitational direction and friction coefficient.

References

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[3] T. Yoshimitsu et al., "New Mobility System for Small Planetary Body Exploration," Proc. of IEEE Int. Conf. on Robotics and Automation (ICRA), pp.1404–1409, 1999.

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[5] T. Yoshimitsu et al., "Autonomous Navigation and Observation on Asteroid Surface by Hopping Rover MINERVA," 6th Int. Sympo. on Artificial Intelligence, Robotics and Automation in Space (i-SAIRAS), No.AS017, 2001.