Development of hopping rovers for a new challenging asteroid

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Abstract

Japan will launch the second sample return spacecraft "Hayabusa-2" to the Near-Earth asteroid "1999JU3" at the end of 2014.

The spacecraft was being developed in a very short period using the heritage from the previous mission "Hayabusa" which went to the tiny asteroid "Itokawa" in 2005.

The authors are developing a rover system named "MINERVA-II" for Hayabusa-2 mission. MINERVA-II is not a copy of the previous payload onboard Hayabusa.

Since the target asteroid parameters such as gravity, surface temperature, and solar energy density are different from the ones of the previous target asteroid "Itokawa", the rover system has been designed from the beginning using the experience obtained from the past mission. We also face to the cruel temperature on the surface which comes from the low-albedo body as well as the possibly perpendicular rotational axis to the orbital plane.

In this paper, the robotic capabilities on MINERVA-II rover system designed for the new challenging asteroid are described.

1 Introduction

Japan will launch the second sample return spacecraft "Hayabusa-2" to the Near-Earth asteroid "1999JU3" at the end of 2014[1].

The predecessor spacecraft "Hayabusa" made a great success when it returned to the Earth in June 2010 with a capsule containing some particles obtained from the S-type asteroid "Itokawa"[2].

The authors installed a tiny hopping rover called "MINERVA" into Hayabusa mission ten years ago. The rover weights only 591[g] with a sophisticated mobile system and an autonomous exploration capability over the microgravity environment of small solar system bodies[4].

MINERVA was deployed from the mother spacecraft on 12 November 2005 at the vicinity of the target asteroid. Unfortunately it became a solar orbiting satellite since the deployment condition was bad. Nevertheless it worked well, demonstrating an autonomous capability and had survived until the communication link was lost[5].

The authors are again developing an another rover system named "MINERVA-II" for Hayabusa-2 mission. The total concept is the same but this time multiple rovers are installed.

MINERVA-II is not a copy of the previous payload onboard Hayabusa. Since the target asteroid parameters such as gravity, surface temperature, and solar energy density are different from the ones for the previous target, the rover system has been designed from the beginning using the experience obtained from the past mission. We also face to the cruel temperature on the surface which comes from the low-albedo body as well as the rotational axis possibly perpendicular to the orbital plane[3] .

In this paper, the robotic capabilities on MINERVA-II rover system designed for the new challenging asteroid is described.

2 Rovers

The spacecraft accommodates three rovers from Japan. All the rovers have hopping mobile systems to explore over the surface after the deployment from the mother spacecraft at the vicinity of the target asteroid.

One of the three rovers is being developed by a group of the members gathered from several universities. The authors are in charge of the another two ones, which are basically composed of the identical devices with some minor differences in coping with the cruel thermal condition on the surface.

This section briefly describes the rover system of our responsibility.

2.1 Mobile system

The hopping mobile system over the microgravity environment of the asteroid surface is inherited from the one we used for MINERVA rover.

There is a torquer inside the body and rotating the torquer makes the rover hop into the free space by a repulsive force against the surface. During a short duration after the start of the torquer, the interaction between the rover body and the surface acquires a lateral acceleration by the friction, which eventually provides the rover with a horizontal hopping speed.

Once having hopped into the free space, the rover makes a ballistic movement and return to the surface sometime unless the initial hopping speed exceeds over the escape velocity from the surface.

The actually adapted mobile system this time has two orthogonal DC motors with a mass of the flywheel. The simultaneous rotation of two DC motors makes the rover hopping in the aimed direction with a controlled speed.

The method was evaluated by some microgravity experiments using the drop tower at ZARM, Bremen, Germany, and in the parabolic flights departing from Bordeaux, France.

2.2 Autonomous exploration

The rover is equipped with a MEMS three-axis gyro, an accelerometer, and eight photo diodes for the autonomous navigation.

The rover is always calculating its attitude using the gyro to estimate whether it is hopping or is still on the surface.

When the rover is on the surface sitting still, it takes a hopping action to move for the different place after making a surface observation by the scientific sensors.

During the ballistic motion in the free space, the rover just captures the surface images periodically. Photo diodes are used to estimate the solar direction.

2.3 Scientific Sensors

The rover is equipped with some cameras. The number of cameras is dependent on the budget we can use this year, but maximum of four cameras can be installed in one rover.

Two cameras with a very wide field of view are oriented to the opposite directions to cover as many areas as possible. These cameras can capture the scenery with a small distortion less than 3[%] in 125[deg] of FOV and are used to shoot the asteroid surface when the rover is hopping.

Another two cameras with a narrow FOV are installed on the same place of the rover with a baseline of 3[cm]. These are used as a stereo pair of the cameras to simultaneously capture the nearby surface when the rover is on the surface.

The thermometers and the potential sensors are also install in the rover to directly measure the surface properties of the asteroid when the rover is on the surface.

2.4 Survival capability

The rotational axis of the target body has not yet identified by the observation from the Earth.

There may be the situation where the rotational axis is perpendicular to the revolution plane. In that case, a very long daytime and a very long nighttime are iterated. The rovers are very tiny and the temperatures of the installed devices are rapidly synchronized to the surface temperature, which is absolutely above the working temperature. This will suspend the exploration of the rover for a long time.

One of the two rovers on our responsibility has a shutter to change the radiation capability of the rover body. A survival technique to close the shutter for isolating the heat transfer from the surface as well as to open the shutter for actively getting the heat away is to be equipped for prolonging the exploration duration.

3 Conclusion

This paper briefly describes the MINERVA-II rover system onboard Hayabusa-2 asteroid mission scheduled to launch this December. The rovers are not yet completed and the authors will have a maximum effort to develop the rovers before the launch.

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