

MINERVA Rover which Became a Small Artificial Solar Satellite

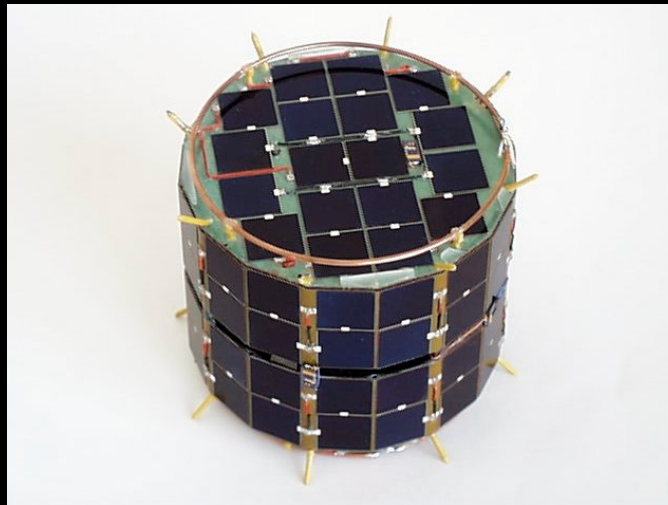


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Small Satellite Conference

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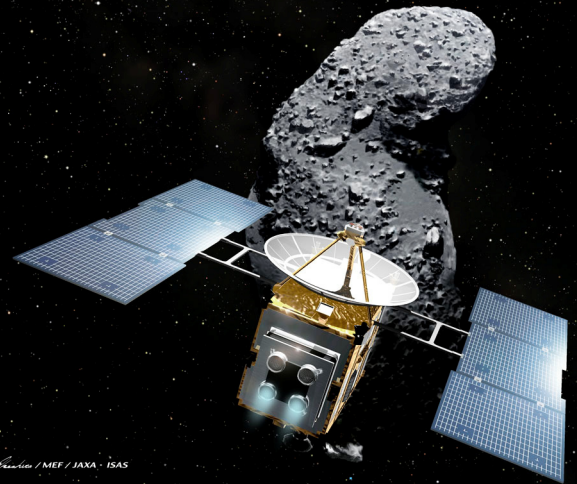
MINERVA

- Micro/Nano Experimental Robot Vehicle for Asteroid
- installed in HAYABUSA spacecraft
 - Japanese asteroid explorer (launched in 2003)
- very small, light-weighted and made in low cost
 - mass: 591[g]
 - size: diameter 120[mm] x height 100[mm]
 - Pico-sized spacecraft



HAYABUSA

- sample return mission from asteroid
- target asteroid “ITOKAWA”
 - size: 535 x 294 x 209[m]
- launched on 9 May, 2003.
- rendezvous at ITOKAWA in Sep, 2005.
- touchdowns to ITOKAWA in Nov, 2005.
- will depart from orbit of ITOKAWA in 2007.
- will be back to the Earth in 2010.



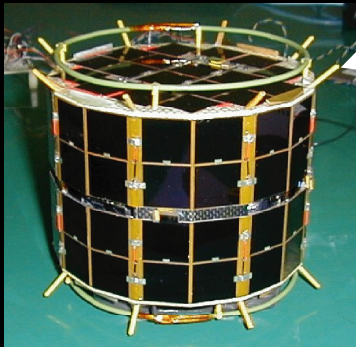
MINERVA mission objectives

to conduct a surface exploration over a small planetary body

- technical experimental rover
 - hopper
 - evaluation of hopping mobile system on micro-gravitational surface
 - autonomous exploration
 - demonstration of fully autonomous exploration
 - another technical challenges
 - use of new devices (electrical double-layer capacitor etc) and commercial devices (camera etc)
 - new concept of thermal control on severe asteroid surface
 - simple deployment mechanism
 - onboard data evaluation and selection
- scientific contribution by onboard cameras, thermometers and technical analysis.

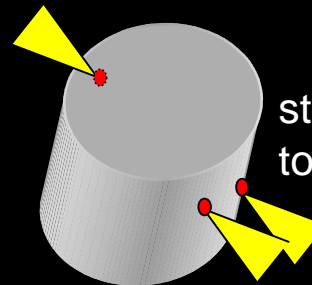
MINERVA rover specification

size	hexadecagonal pole (diameter: 120[mm], height: 100[mm])
mass	591[g]
onboard computer	32bit RISC CPU (clock:10[MHz]) ROM: 512[kB], RAM: 2[MB], FlashROM: 2[MB]
actuators	DC motor × 2
mobile system	hopping (max 9[cm/s]@rigid surface)
power supply	solar cells: max: 2.2[W] @1[AU] from Sun capacitors: 5[V],25[F]
communication	9,600[bps] (half duplex, max distance: 20[km])
sensor(navigation)	photo diode × 6, thermometer × 4
sensor(science)	color CCD camera × 3, thermometer × 6
temperature range	-50 ~ +80 [C] (automatic shutdown @ -50,+80[C])
life	3[asteroid days] (1[asteroid day]=12.15[h])



thermometer

a camera for distant terrain



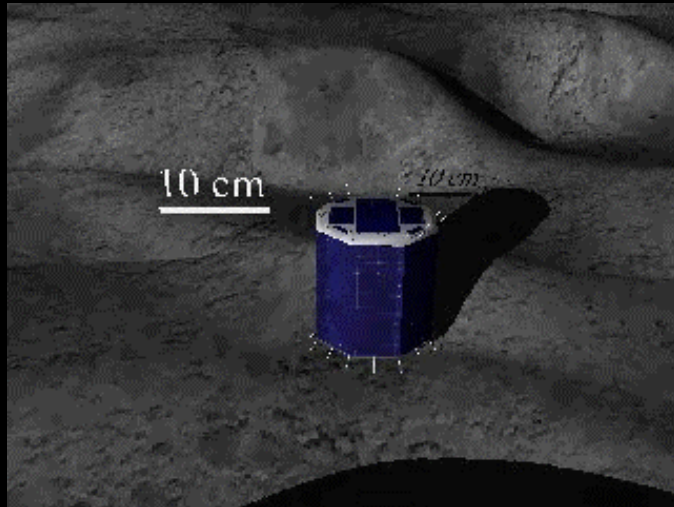
stereo pair of cameras to view near side.



Summary of MINERVA mission

- The rover was deployed on Nov 12, 2005 when HAYABUSA was very close to ITOKAWA.
- In-situ observation on the asteroid surface was not conducted because the rover did not arrive at the asteroid. It became an artificial planet.

Supposed exploration and surface image



Surface exploration by hopping



Image of asteroid surface
(made by clay)

Deployment

- MINERVA was deployed on 12 November, 2005
 - Rehearsal of touchdown
 - Hayabusa did not land on the asteroid.
 - Hayabusa touched the asteroid on 19 Nov and 25 Nov.
 - Deployment was triggered by sending a command from the Earth.
- Deployment supposed
 - relative S/C speed to the asteroid: less than 5[cm/s]
 - altitude: 70[m]
- Four photographings by the camera onboard Hayabusa (ONC-W1) were scheduled.

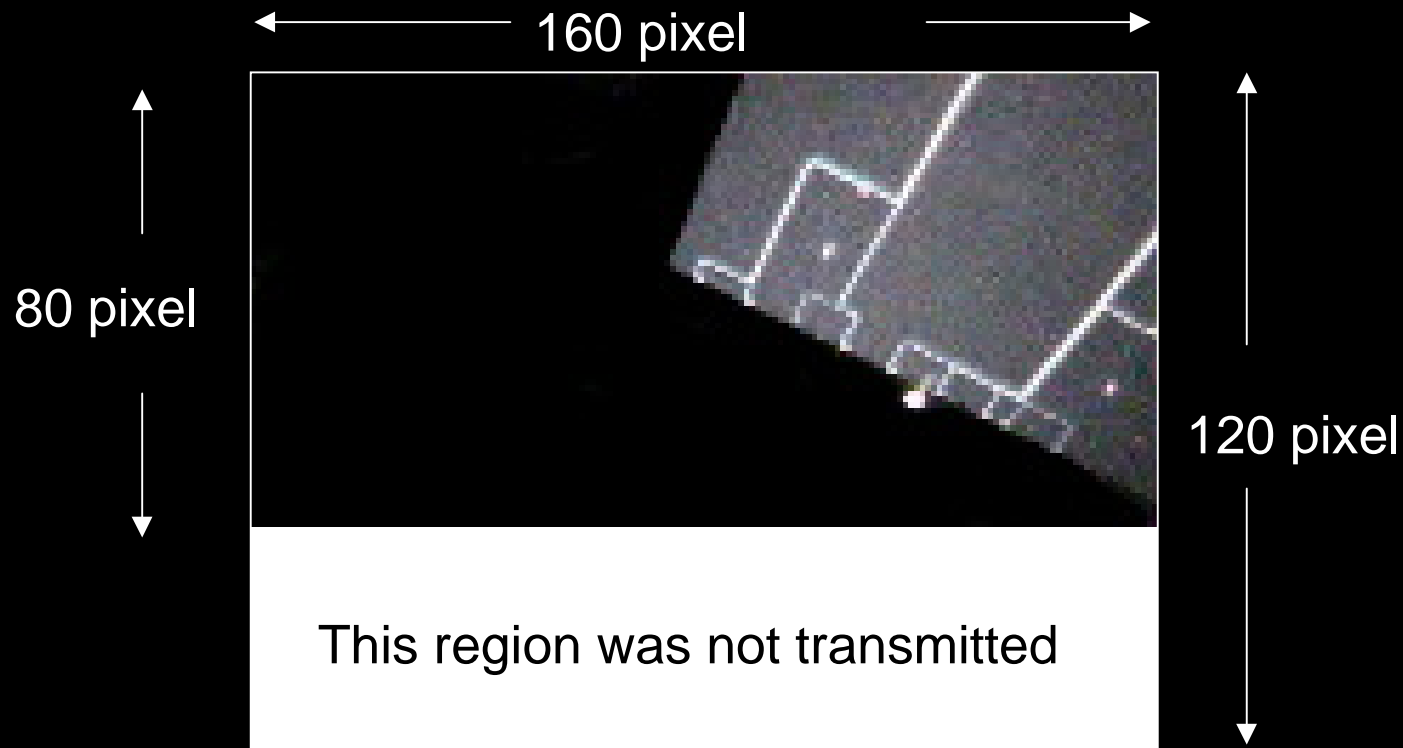
Actual deployment

06:08 UT		command transmission from the ground
06:24	0	deployment
06:24:20		first HK packet generation after the deployment
	+120[sec]	S/C maneuver of +30[cm/s] getting away from asteroid
	+212	shooting of MINERVA by ONC-W1 (1)
	+250	shooting of MINERVA by ONC-W1 (2)
	+300	shooting of MINERVA by ONC-W1 (3)
	+480	shooting of MINERVA by ONC-W1 (4)
06:40		confirmation of the deployment on the ground

- Deployment was conducted
 - working mode of the rover shifted to “autonomous”
 - onboard status estimation by the rover shifted to “hopping” because MINERVA was tumbling.
 - Actual deployment
 - relative S/C speed to the asteroid: +15[cm/s]
 - altitude: 200[m]
- MINERVA became a smallest solar orbiting artificial satellite.
(Guinness world record?)

Obtained image by MINERVA

- Only one image was transmitted to HAYABUSA after the deployment.
- Solar paddle of HAYABUSA is included in the image.

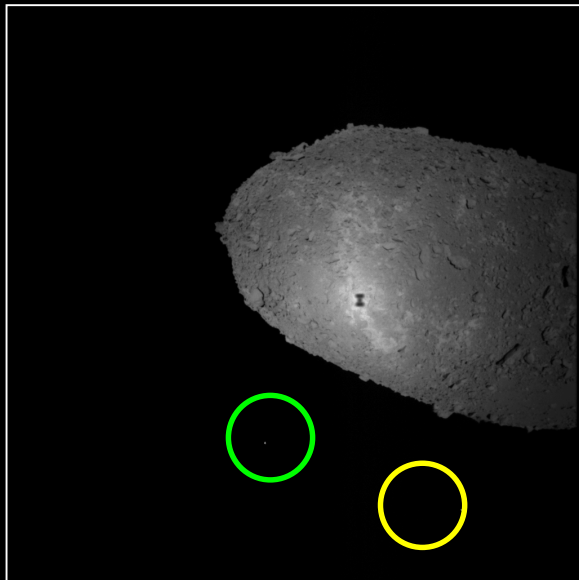


- One third of the image was not transmitted to HAYABUSA.
- The rover evaluates the obtained images. The region with no objects in the image is not stored.
- The image is thrown away if there is nothing in the image,

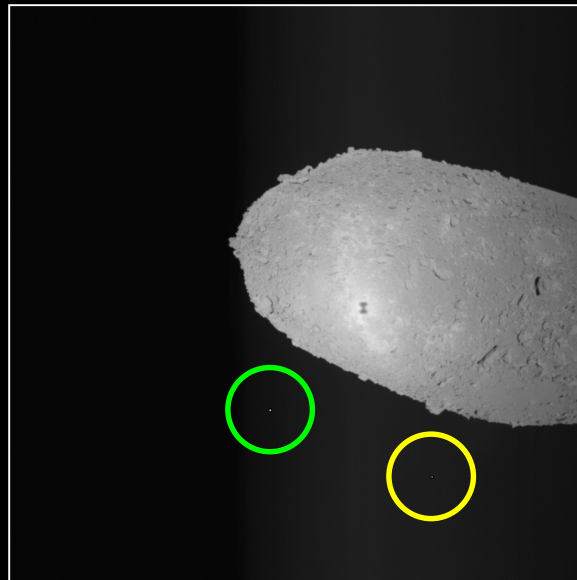
MINERVA shot by Hayabusa camera

Images obtained by HAYABUSA camera (ONC-W1)

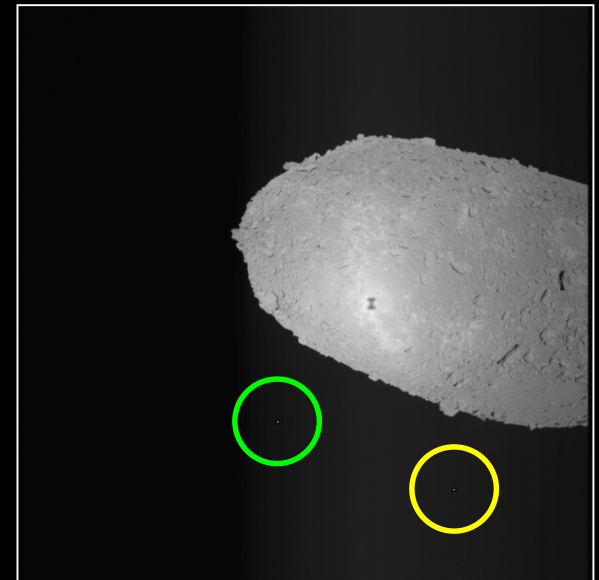
- The rover and the cover are found in the images.



212[sec]



250[sec]

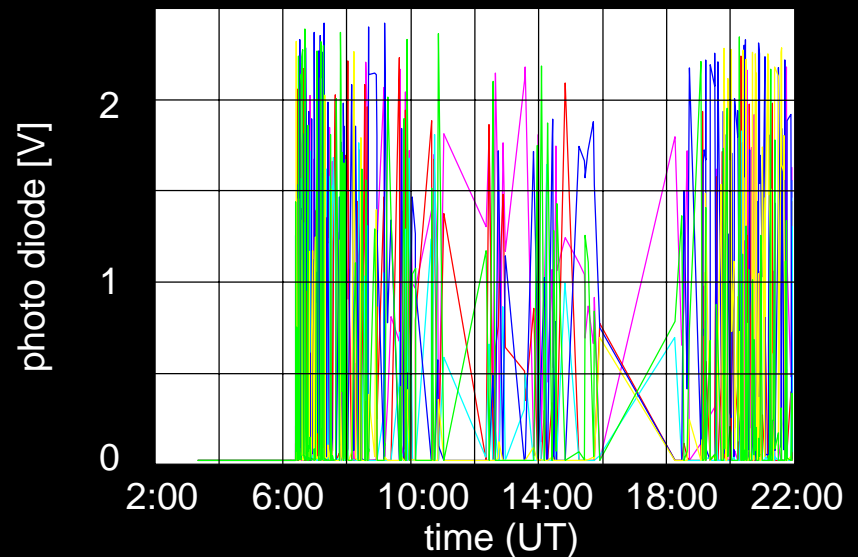
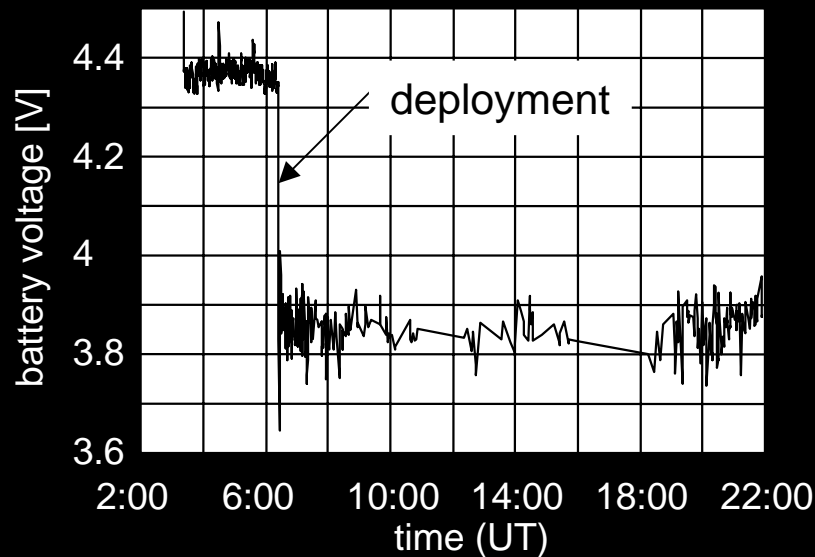


300[sec]



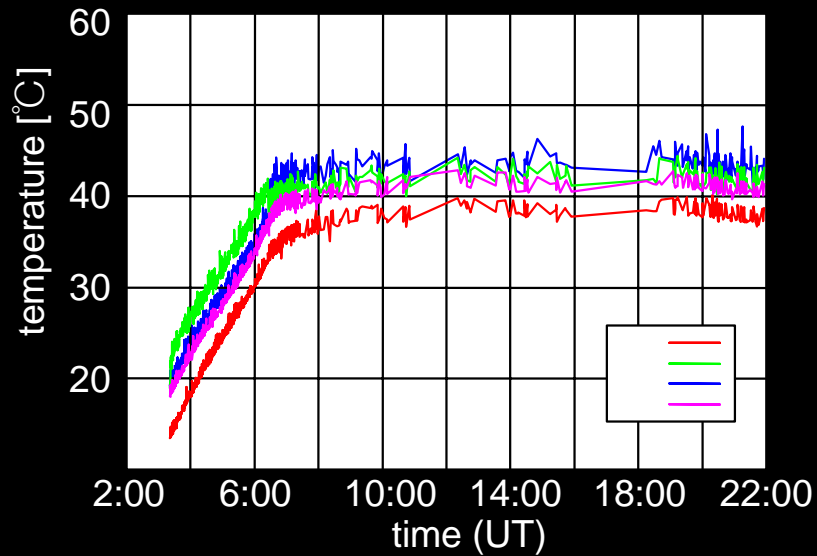
Telemetry from rover

- The communication link between the rover and HAYABUSA was continuously established for 18[hour] after the deployment.
 - Last telemetry: 13 November 00:32:20 UT
- The link was lost because the rover went out of the coverage of the antenna of HAYABUSA.
 - The rover was very healthy at the last telemetry.

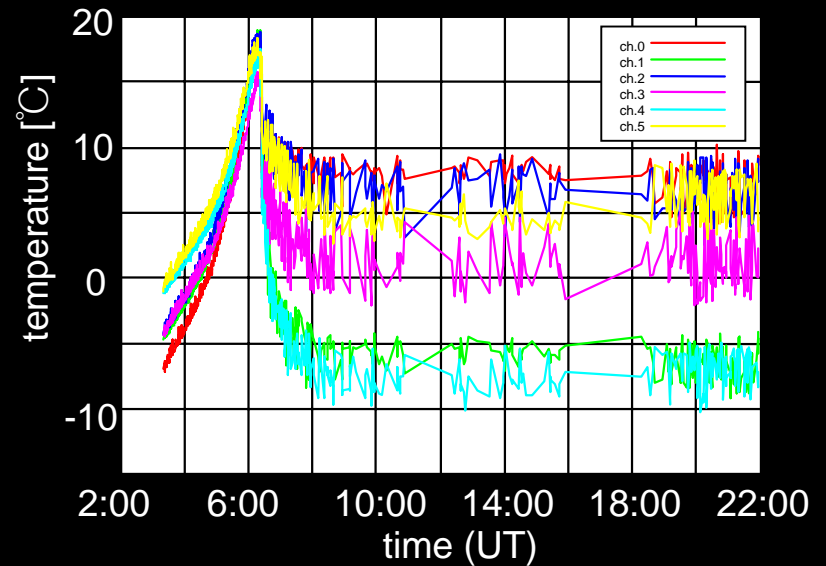


Telemetry from rover

temperature measured



(a) device temperature .



(b) outside temperature measured at the tip of the pins.

Summary

- The rover was deployed on Nov 12, 2005 when HAYABUSA was very close to the asteroid ITOKAWA.
- The rover did not arrive at the asteroid. It became an artificial solar orbiting satellite.
- The rover may be alive because its status was very healthy and constant at the last link.
- The rover will fly by the Earth in the near future because its orbit is almost equal to the asteroid ITOKAWA.

The End

Thank you for your attention

