LIDAR in HAYABUSA Mission

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Agenda

- Outline of HAYABUSA Mission
- How to use LIDAR?
- LIDAR System & components
- Lessons Learned
- Ranging Data at Touchdown
- Conclusion
HAYABUSA Objectives

HAYABUSA is Spacecraft to demonstrate following technology and to observe small asteroid Itokawa.

- Operation of Ion Engines for more than
- Earth Gravity Assist with Ion Engines
- Rendezvous with Itokawa with Autonomous Navigation
- Scientific Observation of Itokawa
- Touch-down and Sample Collection
- Return and Recovery of Capsule
HAYABUSA Today

Launched
   May 9, 2003
Earth Swingby
   May 19, 2004
Arrival at Itokawa
   September 12, 2005
First touchdown
   November 19, 2005
Second Touchdown
   November 25, 2005
Preparation to return voyage
   Now
Rendezvous and Landing Sequence

Spacecraft Trajectory

GP (Gate Position) Acquisition
Global Mapping, Remote Sensing
Gravity and Solar radiation estimation,

HP (Home Position) Keeping
Remote Sensing
Detailed Global Mapping,

Approach by RCS

Earth Direction

R&RR
$\Delta = 2000 \text{km}$

50,000km

R&RR + ONC
$\Delta = 2 \sim 3 \text{ km}$

50km

R&RR + ONC + LIDAR
$\Delta = 6 \text{ m}$

50m

R&RR + ONC + LRF

Signal Level 60dB
Boottom Panel View of HAYABUSA

- Telescopic Camera (ONC-T)
- ISAS Robot Lander MINERVA
- Sample Collector Horn
- Laser Range Finder
- Sample Recovery Capsule
- Start Tracker (STT)
- Medium Gain Antenna
- Near Infrared Spectrometer
- Fan Beam Sensor (one of four)
- Wide-angle Camera (ONC-W1)
- X-ray Fluorescent Spectrometer
- Target Marker
- Solar Array Panel
- LIDAR
# HAYABUSA LIDAR

<table>
<thead>
<tr>
<th>Items</th>
<th>Specification</th>
</tr>
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<tbody>
<tr>
<td>Range</td>
<td>50m～50km</td>
</tr>
<tr>
<td>Accuracy</td>
<td>±1m(@50m)</td>
</tr>
<tr>
<td>Repetition Rate</td>
<td>1Hz</td>
</tr>
<tr>
<td>Laser</td>
<td>Q-SW, Nd:Cr:YAG</td>
</tr>
<tr>
<td>Wave length</td>
<td>1064 nm</td>
</tr>
<tr>
<td>Output Power</td>
<td>8 mJ</td>
</tr>
<tr>
<td>Pulse Width</td>
<td>14 nsec</td>
</tr>
<tr>
<td>TX Beam Width</td>
<td>φ 1.7 mrad (1/e^2)</td>
</tr>
<tr>
<td>RX FOV</td>
<td>φ 1 mrad</td>
</tr>
<tr>
<td>RX Optics</td>
<td>Casegren φ 126 mm、SiC</td>
</tr>
<tr>
<td>Weight</td>
<td>3.7kg</td>
</tr>
<tr>
<td>Include: DC/DC, Radiator</td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td>17.0W (+LD Heater max5W)</td>
</tr>
<tr>
<td>Size</td>
<td>240mm×228mm×250mm</td>
</tr>
<tr>
<td></td>
<td>Radiator: 240mm×300mm</td>
</tr>
</tbody>
</table>
Block Diagram of LIDAR

OUTPUT DATA (to AOCU)
- RANGE and STATUS (Valid/Invalid)
- SIGNAL LEVEL (TX/RX Level Monitor)
- STATUS (MODE, GAIN, etc)
RX Casegren Telescope

FOV: 1 mrad
SiC: Small Thermal Expansion

Surface Irregularity 0.18 μmP-V

Main Reflector  Truss  Sub Reflector
Hayabusa LIDAR

YAG Laser Resonator

- Single Mode Q-Switched Diode Pumped Nd:YAG
- LD is thermally controlled between 30 and 35 degrees by thermostat to tune LD wave length to the absorption line.
- Some protective windows are installed to avoid radiation damage due to contaminations.
- Pockels Cell is driven by 2.7kV high voltage driver.
- Output Laser is expanded by expander with magnification of 3.
Lessons Learned

- Deterioration of LD
- Damaged by contamination
- LiNbO3
- Thermal Vacuum test
Stability of On Board Counter

- Range Error of LIDAR 1-

Accuracy 300ps

Hayabusa LIDAR
Signal Level Dependency
- Range Error of LIDAR 2 -

Fixed Length Optical Fiber

RX Level (0～255)

Range (m)

42m
Field Experiment with PM at Uchinoura
Oct. 2001

From Tracking Radar to 20m Antenna

<table>
<thead>
<tr>
<th>Target</th>
<th>Measured Range (m)</th>
<th>σ (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edge of Main Reflector</td>
<td>3313</td>
<td>1.5</td>
</tr>
<tr>
<td>Edge of Sub Reflector</td>
<td>3323</td>
<td>1.9</td>
</tr>
</tbody>
</table>

20m Φ Antenna
Laser Light from LIDAR
Tracking Radar Site
LIDAR First Light

- Date and Time (UST): 09/10 00:00:00 to 09/12 12:00:00
- Range (m): 0 to 70000
- RX LEVEL (count): 0 to 40

- 9/10 4:26:26: 48602m
- 9/10 5:55:18: 47182m
- 9/10 6:07:51: 46970m

- TX level
- Gate Position: 48.6km
- GP
- RX Signal Level: 30cm/sec
Ranging Result at First Landing

19 Nov. 2005
LIDAR Operation History

Graph showing the operation history of LIDAR, indicating key events such as arrival, first approach, second and third approach, first touchdown, second touchdown, and return signal over time. The graph plots range (m) on the y-axis and time on the x-axis.
Calibration with shadow of HAYABUSA

<table>
<thead>
<tr>
<th>LIDAR Range (m)</th>
<th>Calculation from shadow (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>188.5</td>
<td>188.6</td>
</tr>
<tr>
<td>39.9</td>
<td>43.3</td>
</tr>
<tr>
<td>38.5</td>
<td>42.9</td>
</tr>
</tbody>
</table>

Good agreement!

No Range Bias.
Measurement of ITOKAWA Surface

- Tukuba boulder with 3-4m height was identified
- A possible rock fissure was also identified
- Rough Terrain: Surface roughness near Tsukuba Boulder: 2.2m
- Smooth Terrain: Surface roughness in the Muses Sea: 0.6m

Gravity (Mass) Estimation of ITOKAWA
=> Science June 2 2006
Conclusion

- Three month LIDAR operation is successfully performed with 4.1 million laser shot.
- No Laser power degradation was observed.
- HAYABUSA had successfully rendezvoused with ITOKAWA by LIDAR data.
- HAYABUSA had successfully touchdown based on its navigation sensor including LIDAR.
- LIDAR detected the range from 50km to 30m.
- LIDAR data will provide important surface information of ITOKAWA.