Development of Reflectors for Motion Grasp of Space Debris

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1. Introduction

Goal:
① To develop a small and cost-effective laser ranging arrays (LRAs) for satellite laser ranging (SLR)
② To mount onto upper stages of a rocket that are disposed of without controlled re-entry

Outcome:
① Grasp of motion of space debris
   - Importance of motion grasp in the active debris removal (ADM)
   - No case where the motion of upper stages of a rocket is measured
   - Capability of SLR to measure target’s rotational motion by kHz ranging
② Improvement of accuracy and precision of orbit determination in re-entry prediction
   - Increase of observational data

2. Details of LRA

A) Overview of CCRs

- The LRA consists of only seven corner cube reflectors (CCRs)
- CCRs typically consist of three mirrors or reflective prism faces which reflects an incident light beam directly towards the source.
- Specification of CCRs

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Material (CCR)</td>
<td>Fused Silica</td>
</tr>
<tr>
<td>2</td>
<td>Height [mm]</td>
<td>19.05</td>
</tr>
<tr>
<td>3</td>
<td>Diameter [mm]</td>
<td>25.40</td>
</tr>
<tr>
<td>4</td>
<td>Dihedral angle offset ['']</td>
<td>+1.0</td>
</tr>
<tr>
<td>5</td>
<td>Coating</td>
<td>Uncoated</td>
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</tbody>
</table>

C) Rocket interface

- The range in which the LRA responds to the laser pulse is ± 45 degrees at the zenith angle
- Six LRAs are necessary if covering all directions
- Five LRAs are planned to be mounted onto upper stages of a rocket with screws

B) Overview of body frame

- CCRs are aligned into each holes of the body frame
- The drawing of the body frame
- Resin model of the body frame of developing LRA manufactured by a 3D printer (JAXA); 7 CCRs are aligned into each holes.
- Specification of body frame

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Material (Body)</td>
<td>Aluminum</td>
</tr>
<tr>
<td>2</td>
<td>Material (contact portion b/w body and CCR)</td>
<td>Silicon rubber</td>
</tr>
<tr>
<td>3</td>
<td>Height [mm]</td>
<td>31</td>
</tr>
<tr>
<td>4</td>
<td>Diameter [mm]</td>
<td>110</td>
</tr>
<tr>
<td>5</td>
<td>Weight [g]</td>
<td>Less than 300</td>
</tr>
<tr>
<td>6</td>
<td>Angle b/w central axes of adjacent CCRs [deg]</td>
<td>30.0</td>
</tr>
</tbody>
</table>

3. Roadmap of development

- CAD model: complete!
- Resin model: complete!
- Experimental model (EM): finish until Dec. 2018
- Flight model (FM): finish until Jan. 2019
- Mount onto a H-IIA rocket: finish until Feb. 2019

4. Conclusion and future work

- JAXA is steadily developing small and cost-effective LRAs which is mounted onto upper stages of a rocket.
- LRA will be finally developed at approx. US$3,500/piece.
- JAXA is aiming to standardize the installation of the developed LRA on the upper stage of a rocket (at least made in Japan).
- Selling developed LRAs or distributing design drawings are under consideration.