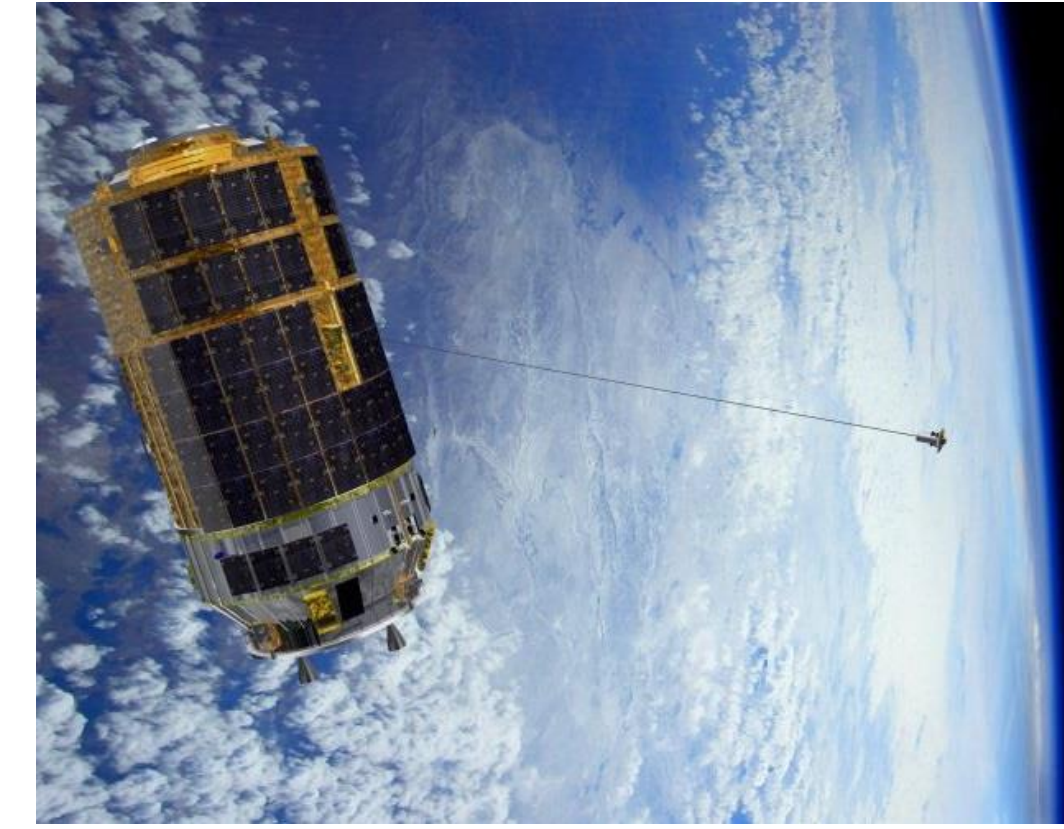


## 1. Introduction

- 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



Active debris removal using electrodynamic tethers (JAXA)

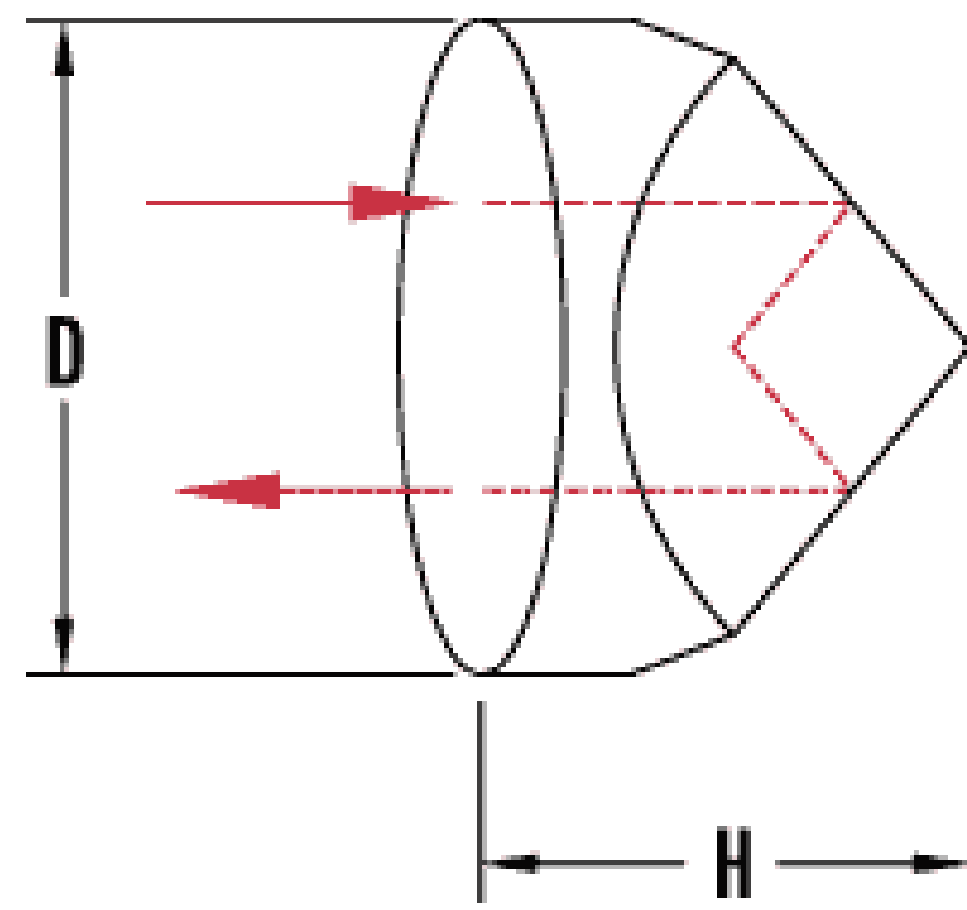
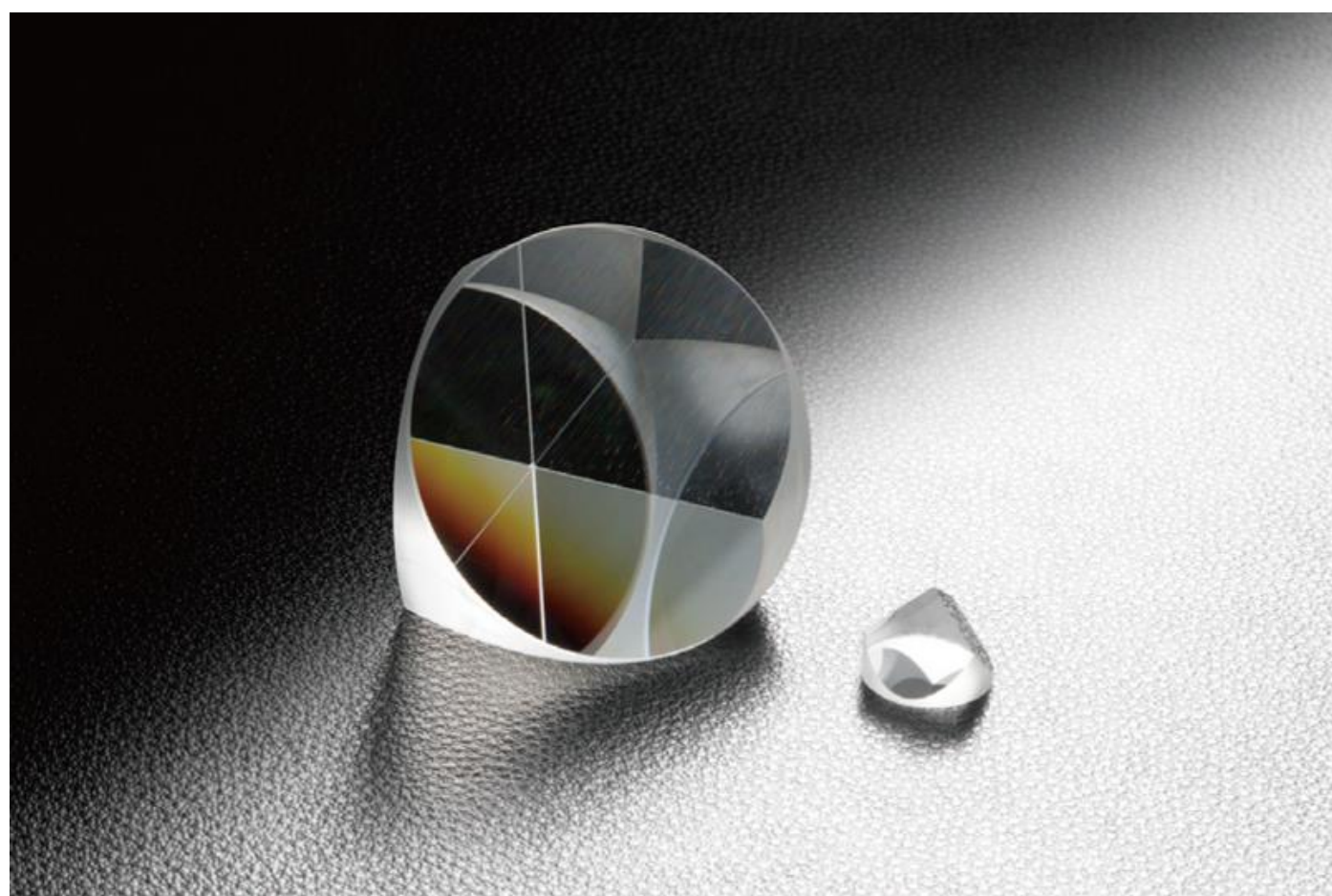


The main propellant tank of the second stage of a Delta 2 launch vehicle landed near Georgetown

## 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

No.	Item	Specification
1	Material (CCR)	Fused Silica
2	Height [mm]	19.05
3	Diameter [mm]	25.40
4	Dihedral angle offset ["]	+1.0
5	Coating	Uncoated

There is a possibility that these specifications are modified.

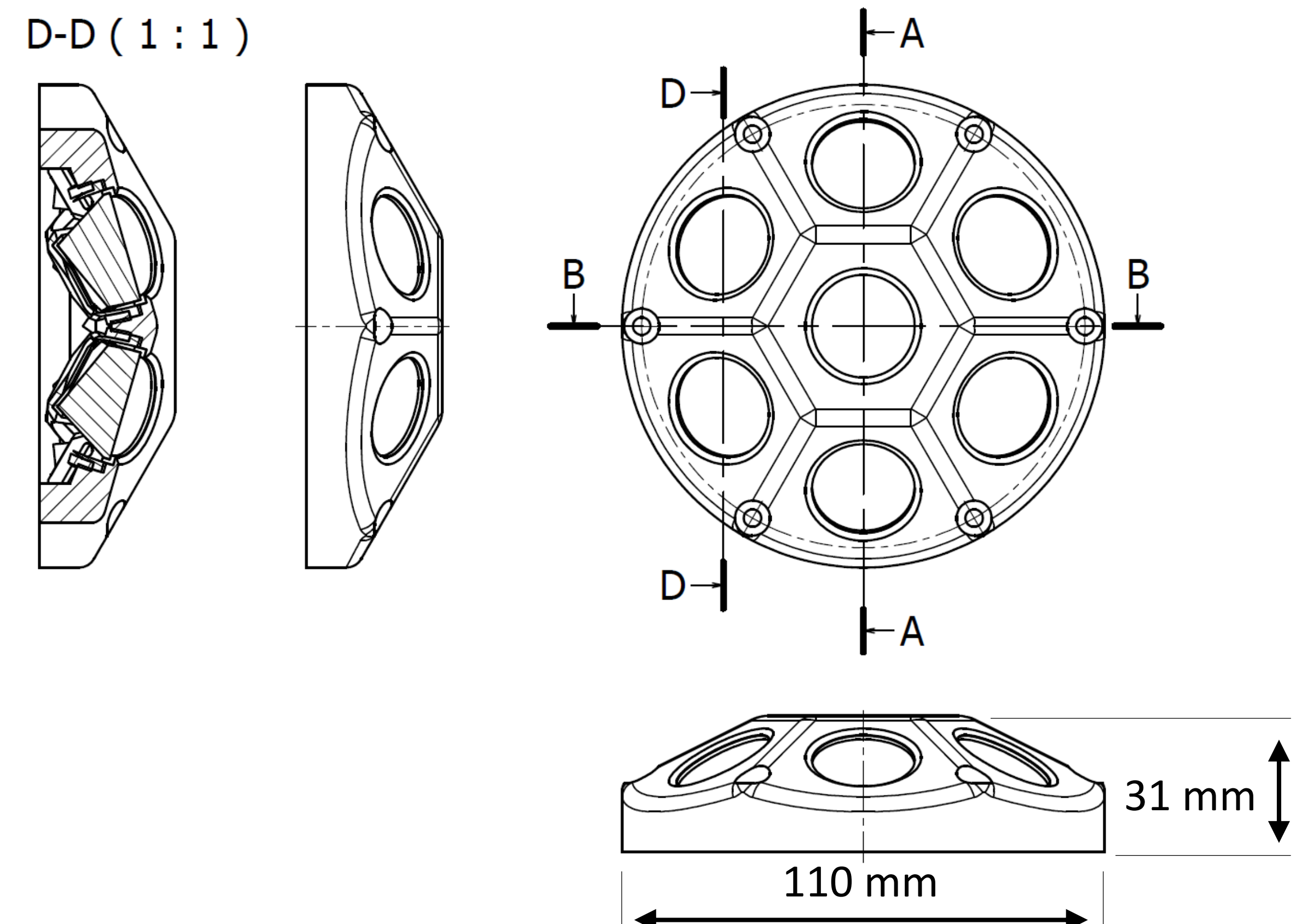
### B) Overview of body frame

- CCRs are aligned into each holes 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.

- The drawing of the body frame



A part of the drawing of the body frame. Some information is erased.

- Specification of body frame

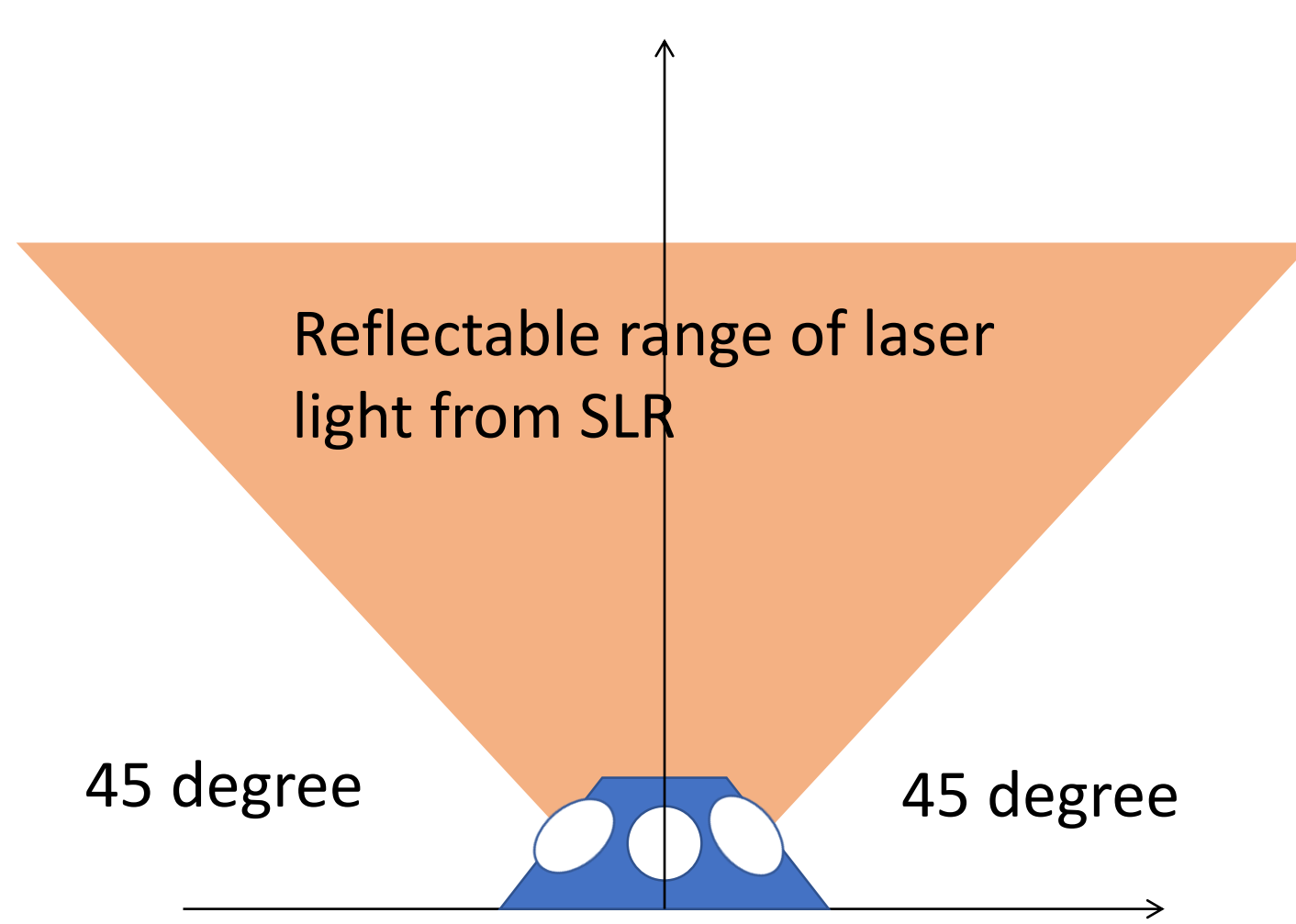
No.	Item	Specification
1	Material (Body)	Aluminum
2	Material (contact portion b/w body and CCR)	Silicon rubber
3	Height [mm]	31
4	Diameter [mm]	110
5	Weight [g]	Less than 300
6	Angle b/w central axes of adjacent CCRs [deg]	30.0

There is a possibility that these specifications are modified.

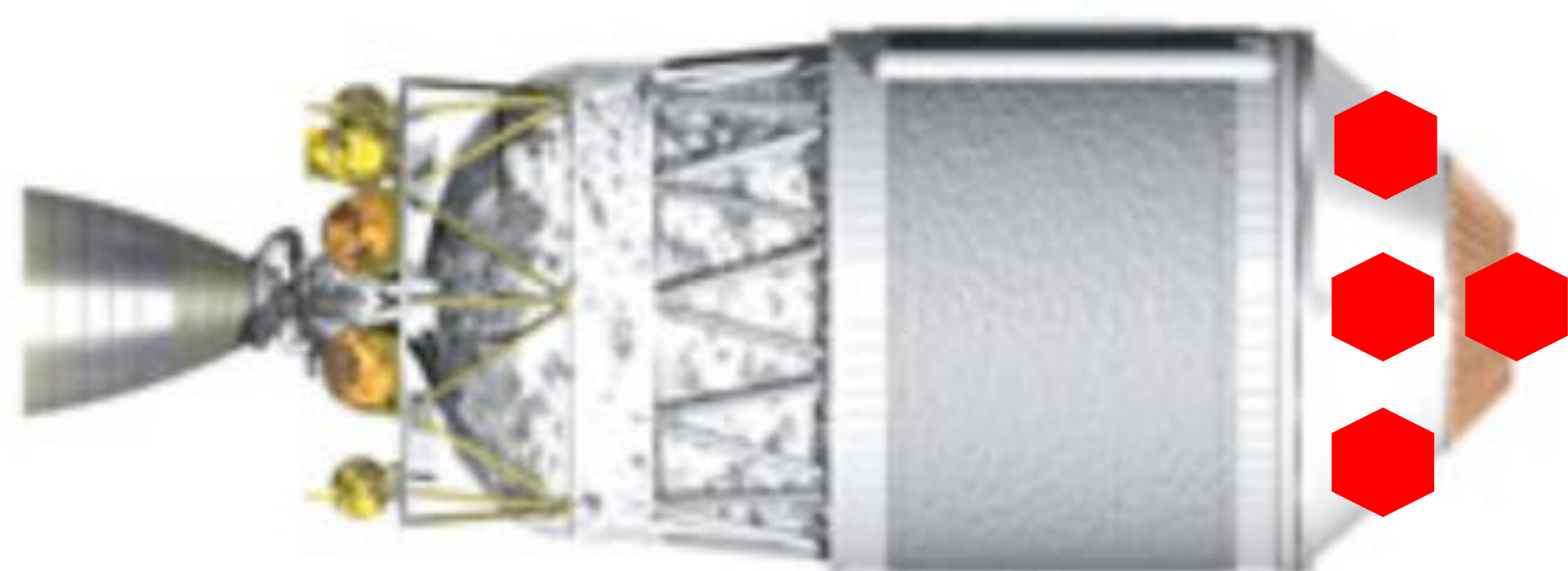
### C) Rocket interface

- The range in which the LRA responds to the laser pulse is  $\pm 45$  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



Rocket interface of LRAs; ● is the LRA; another LRA is onto back-side of the rocket. There is a possibility that the interface is modified.

## 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.