Technical Information for PROBA-2 Laser Tracking Support

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The PROBA-2 Laser Retro Reflector Array

The PROBA-2 spacecraft [1] carries a Laser Retro Reflector Array (LRA) to support the validation of GPS based orbit determination results [2]. The LRA has been manufactured by the Institute for Precision Instrument Enginering (IPIE), Moscow, and is identical to LRAs used on ESA's GOCE and CryoSat-1/2 satellites. A picture of the retro reflector array is shown in Fig. 1.

Fig.1 IPIE Laser Retro Reflector (GOCE flight model)

The LRA comprises a total of seven individual reflectors made of fused silica with aluminium-coated reflecting prism faces. The central reflector and the six lateral reflectors in circular arrangement are mounted on a flattened cone. The reflector array has a total mass of 0.32 kg and overall dimensions of Ø114 x 51 mm. Other design parameters are summarized in Table 1.

Table 1 Technical parameters of SRIPI Laser Retro Reflector (from [3])

Parameter	Value
Number of reflectors	7
Effective optical aperture of individual reflectors	Ø 28.2 mm
Distance between input face plane and the prism vertex	19.1 mm
Height of center-of-mass above ground plane	19.8 mm
Height of input plane center of central reflector	48 mm
Height of input plane center of lateral reflectors	28.5 mm
Radial offset of input plane center of lateral reflectors	45.5 mm
Tilt angle of lateral reflectors relative to central reflector	57.5°
Field of view	130°
Reference point	Center of base plane
Range correction relative to reference point	19±6 mm

The location and orientation of the individual reflector elements within the LRA is illustrated in Figs. 2-3. For each reflector, Table 2 furthermore provides the coordinates of the input plane centers and the boresight direction in the LRA coordinate system. The base plane constitutes the xy-plane of the LRA coordinate system, and the center of the base plane serves as origin and LRA reference point. The z-axis of the LRA coordinate system coincides with the boresight direction of the central reflector (henceforth numbered as #0) and the x-axis connects two of the lateral reflectors (designated as #1 and #4).

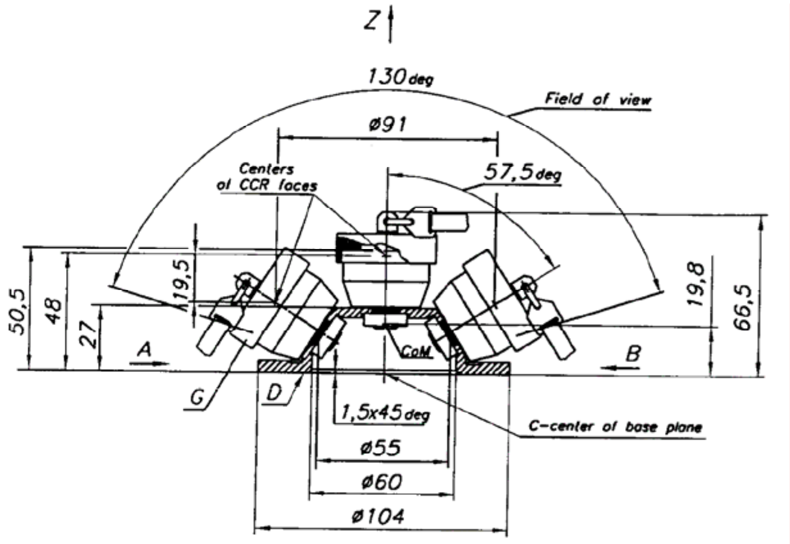

Fig.2 Design drawing of PROBA-2 Laser Retro Reflector Array (side view, [3])

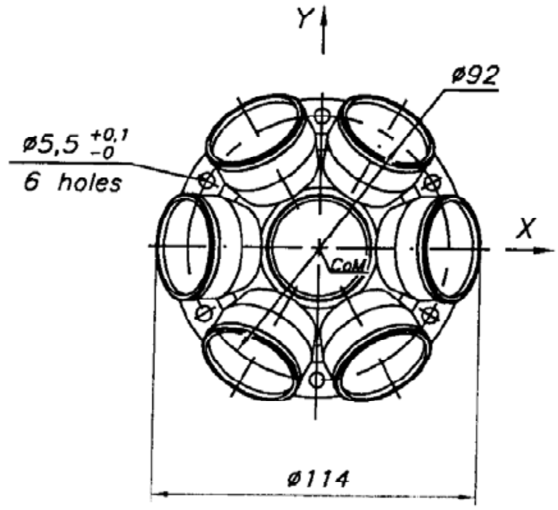

Fig.3 Design drawing of PROBA-2 Laser Retro Reflector Array (top view [3])

Table 2 Location and orientation of the individual reflectors in the LRA reference system

LRR	Location	Center of input plane			Boresight direction		
#		x [m]	y [m]	z [m]	e_x	e_y	e_z
0	central	0.0000	0.0000	0.0480	0.0000	0.0000	1.0000
1	+x	0.0455	0.0000	0.0285	0.5373	0.0000	0.8434
2	+x/+y	0.0228	0.0394	0.0285	0.2686	0.4653	0.8434
3	-x/+y	-0.0228	0.0394	0.0285	-0.2686	0.4653	0.8434
4	-x	-0.0455	0.0000	0.0285	-0.5373	0.0000	0.8434
5	-x/-y	-0.0228	-0.0394	0.0285	-0.2686	-0.4653	0.8434
6	+x/-y	0.0228	-0.0394	0.0285	0.2686	-0.4653	0.8434

Laser Retro Reflector Array Accommodation

The Laser Retro Reflector Array of PROBA-2 is mounted in a corner of the bottom (-X) panel of the spacecraft, which also holds the launch adaptor (Fig. 4). The LRA x-axis is aligned with the spacecraft X-axis, while the y- and z-axes are anti-parallel to the Y- and Z-axes, respectively. Table 3 provides the coordinates of the LRA reference point (i.e. the center of the base plane) as well as the center-of-mass coordinates of the LRA in the spacecraft coordinate system.

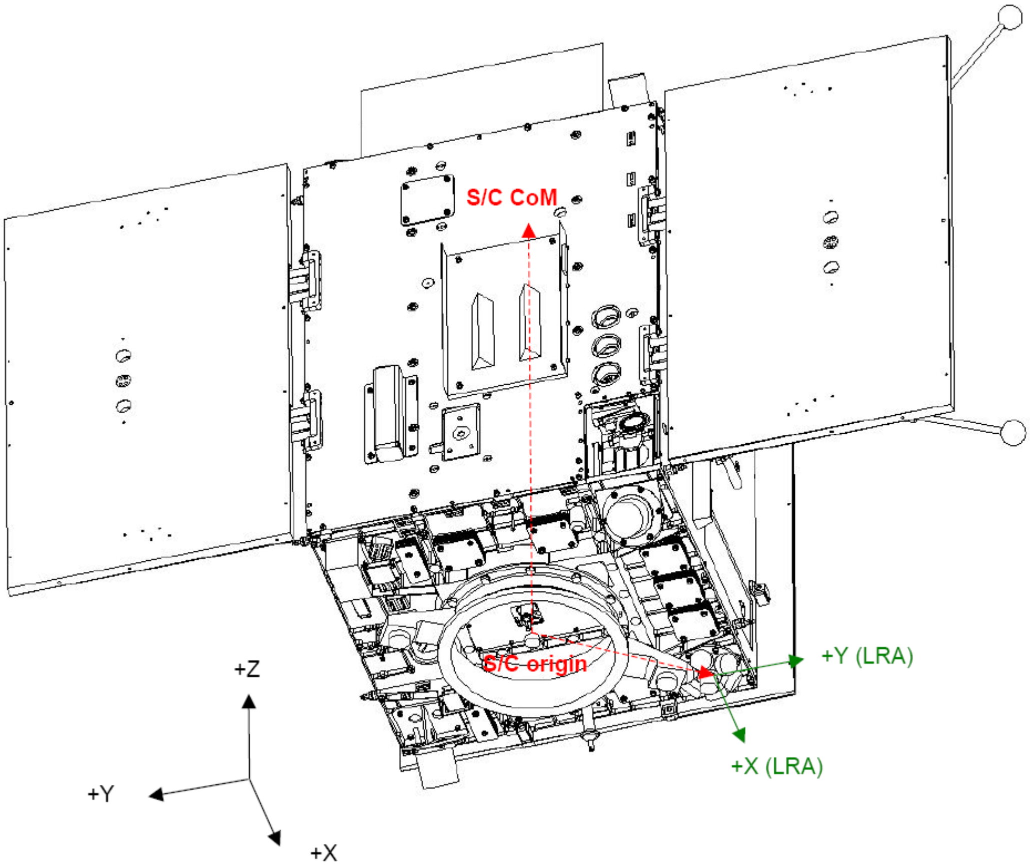

Fig.4 PROBA-2 design drawing showing the location of the laser retro reflector array

Table 3 Location of the LRA coordinates in the spacecraft coordinate system

Point	X [m]	Y [m]	Z [m]
Spacecraft center of mass	-0.0160	-0.0060	+0.3810
LRA center of mass	+0.2085	-0.2390	+0.0102
LRA reference point	+0.2085	-0.2390	+0.0300
Offset of LRA reference point from S/C center of mass	*+0.2245*	*-0.2330*	*-0.3510*

PROBA-2 Orbit and Attitude

PROBA-2 spacecraft will be devoted to solar observations and measurements of the space environment [1] using the "Sun Watcher using APS detectors and image Processing" (SWAP) and the LYman alpha RAdiometer (LYRA). These instruments will provide early warnings of solar eruptions, and constitute a major contribution to ESA's Space Weather project. PROBA-2 will be launched as a co-passenger of ESA's SMOS satellite onboard a Eurockot from the Plesetsk cosmodrome and brought into a Sun-synchronous orbit of 728 km altitude using the re-ignitable Breeze upper stage. For the adopted dusk-dawn orbit the angle between the Sun and the orbital plane (beta angle) is always larger than about 60° and eclipses are confined to a few months during the winter season.

In the Sun Mode, which constitutes the primary observation mode the –x-axis of the spacecraft will be oriented towards the Sun to enable observations with the LYRA and SWAP instruments. In order to maintain the orientation of the Sun image in the instrument frame, the PROBA-2 spacecraft should ideally maintain a fixed attitude throughout the orbit, whereas the star trackers and GPS antennas must always be pointing away from the Earth. As a compromise four rotations of 90° each are conducted at discrete points in the orbit, thus avoiding star sensor obstructions with minimum impact on the science data collection.

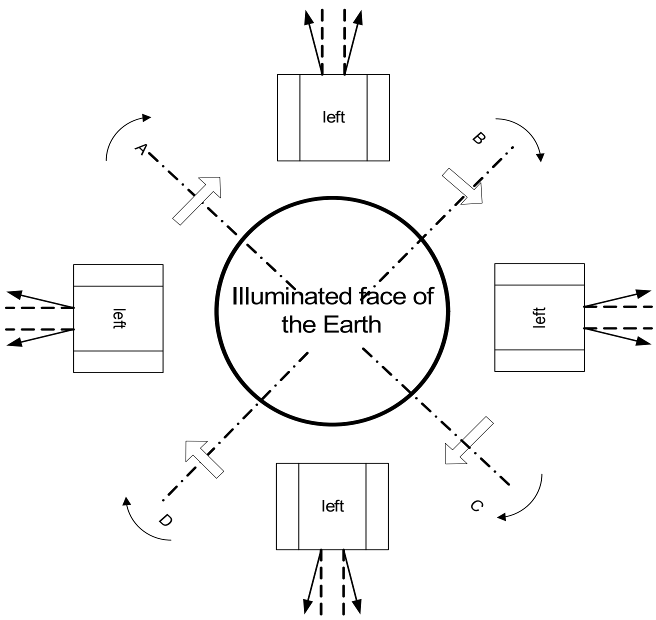

Fig.5 PROBA-2 attitude changes during Sun mode

The proposed orientations in observation mode as seen from the Sun (for a dawn-dusk orbit) are shown in the Fig. 5. Direction arrows on the top panel of the spacecraft indicate the viewing direction of the star tracker heads. The orbit starts with a sun-pointing attitude at the ecliptic plane, at the left side of the figure, where the left (-X) panel including solar arrays and sun observing payloads is pointed towards the sun. The Z-axis lies in the ecliptic plane, facing away from the earth. When moving through the orbit in a clockwise direction, the spacecraft is rotated 90° at 4 points (A, B, C, D) around the LOS of the sun observation payloads. The optimal rotation point will continuously be computed by the AOCS S/W, but will be commanded by the on-board S/W. The rotation points are located 45° from the ecliptic plane. Since the Laser Retro Reflector Array is mounted opposite to the start sensors and GPS antennas it will be pointing towards the Earth with a maximum off-nadir angle of 45° during the Sun mode.

In addition to the standard operations mode, the use of a continued Earth pointing orientation is presently considered for selected experiment phases to enable a thorough validation of the PROBA-2 GPS navigation sensors. During these phases, the LRA will be permanently nadir facing and thus provide optimum conditions for SLR tracking campaigns.

References

[1] Gantois, K., Teston, F., Montenbruck, O., Vuilleumier, P., van den Braembussche, Markgraf, M., “PROBA-2 Mission and New Technologies Overview”, Small Satellite Systems and Services - The 4S Symposium; 25-29 September 2006; Chia Laguna Sardinia, Italy, 2006

[2] Montenbruck O., Markgraf M., Santandrea S., Naudet J., Gantois K., Vuilleumier P.; *Autonomous and Precise Navigation of the PROBA-2 Spacecraft*; AIAA Astrodynamics Specialist Conference, 18-21 Aug. 2008, Honolulu, Hawaii (2008).

[3] V.Shargorodsky; *Technical Description of the Laser Retroreflector array PROBA-2-LRR-01*; Doc. No. К01-Э285-00-00 ТО; Institute for Precision Instruments Engineering, Moscow 2007