Satellite Name: Compass-MS1
Date of Submission: 2015.09.20

SECTION III: RETROREFLECTOR ARRAY INFORMATION:

A prerequisite for accurate reduction of laser range observations is a complete set of pre-launch parameters that define the characteristics and location of the LRA on the satellite. The set of parameters should include a general description of the array, including references to any ground-tests that may have been carried out, array manufacturer and whether the array type has been used in previous satellite missions. So the following information is requested:

Retroreflector Primary Contact Information:

Name: Zhang Zhongping

Organization and Position: Shanghai Astronomical Observatory,Chinese Academy of Sciences. Professor

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Phone No.: 86-21-64696290

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Array type:

○ Single reflector ○ Spherical ○ Hemispherical/Pyramid ◉ Planar

○ other (specify: ______________________)

Attach a diagram or photograph of the satellite that shows the position of the LRA, at the end of this document.

☒ Attached

Attach a diagram or photograph of the whole LRA at the end of this document.

◉ Attached ○ Same as above, Not attached (acceptable only for a cannonball satellite)

Array manufacturer:

NCRIEO, China

Link (URL and/or reference) to any ground-tests that were carried out on the array:

none

Has the LRA design and/or type of cubes been used previously?

○ No ◉ Yes (List the mission(s): This type of cubes was used on the Galileo-101,-102,-103,-104)

For accurate orbital analysis it is essential that full information is available in order that the 3-dimensional position of the satellite center of mass may be referred to the location in space at which the laser range measurements are made. To achieve this, the 3-D location of the LRA phase center must be specified in a satellite-body-fixed reference frame with respect to the satellite's mass center. In practice this means that the following parameters must be available at 1 mm accuracy or better.

Define the satellite-body-fixed XYZ coordinates (i.e. origin and axes) on the spacecraft:
(specify) (add a diagram in the attachment)

see attachment(The Position of the Compass-MS1 Laser Retro-Reflector Array Phase Center)

Relate the satellite-body-fixed XYZ coordinates to a Celestial/Terrestrial/Solar Reference Frame including the attitude control policy:
(specify) (add a diagram in the attachment)

The satellite-body-fixed Z axis always points to the Earth's center.
The satellite-body-fixed X axis is parallel to the direction of satellite flight.

The 3-D location of the satellite's mass center in satellite-body-fixed XYZ coordinates is:

- ○ Always fixed at (0, 0, 0)
- ◉ Always fixed at (-10.1 , -8.4 , -1177.8) in mm
- ○ Time-varying by approximately (_____________) mm during the mission lifetime.
  Will a time-variable table of the mass center location be available on the web?
  ◉ No ○ Yes (URL: ____)

The 3-D location (or time-variable range) of the phase center of the LRA in the satellite-body-fixed XYZ coordinates:

(602 , -80.1 , 2400.8) in mm

The following information on the corner cubes must also be supplied.

The XYZ coordinates referred to in the following are given in:

- ◉ Satellite-body-fixed system (same as above)
- ○ LRA-fixed system (specify below)

(specify the origin and orientation) (add a diagram in the attachment)

List the position (XYZ) of the center of the front face of each corner cube, and the orientation (two angles or normal vector) and the clocking (horizontal rotation) angle of each corner cube. Note that the angles should be clearly defined.

○ Attached at the end of this document
◉ Listed here (acceptable for small number (10 or fewer) of corner cubes)
(specify) (add a diagram in the attachment)

The normal vector of each CCR points to the earth's center.

Is the corner cube recessed in its container (i.e. can the container obscure a part of the corner cube)?
○ No ◉ Yes (specify below)

(specify) (add a diagram)

none

The size of each corner cube: Diameter (33) mm Height (23.3) mm

The material from which the cubes are manufactured (e.g. quartz):
quartz

The refractive index of the cube material
= 1.461 for wavelength λ = 0.532 micron
= see attachment(Refractive Index and Dispersion) as a function of wavelength λ (micron):

The group refractive index of the cube material, as a function of wavelength λ (micron):
= 1.485 for wavelength λ = 0.532 micron
= 1.462@1064nm as a function of wavelength λ (micron):

Dihedral angle offset(s) and manufacturing tolerance (in arcseconds):

1.1+/-0.2aresec

Radius of curvature of front surfaces of cubes:

◉ Not applied ○ Yes (specify: ____________________)

Flatness of cubes' surfaces:

0.1 wavelength

Back-face coating:

◉ Uncoated ○ Coated (specify the material: ____________________)

Other comments on LRA:

(specify) (add a reference to a study of the optical response simulation/measurement if available) (add a diagram if applicable)

none

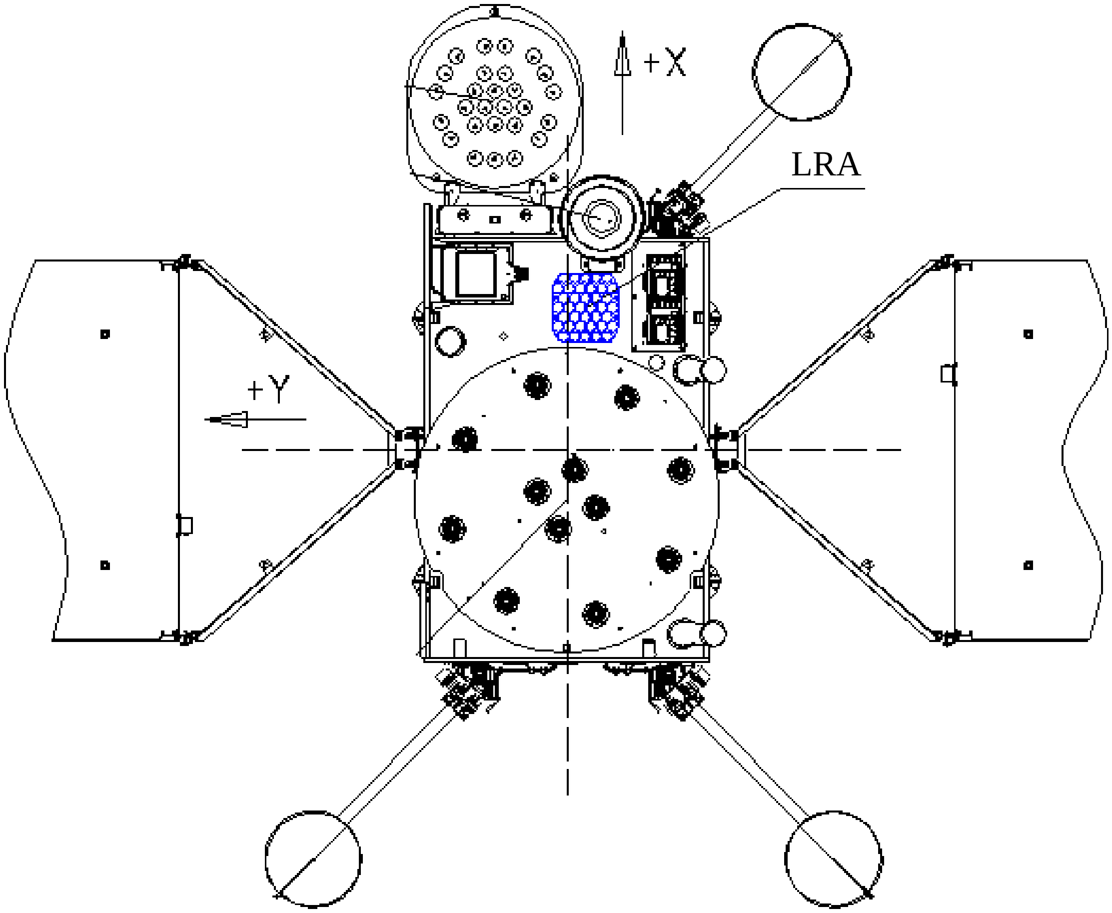


Fig.1 Compass-MS1 satellite and the LRA

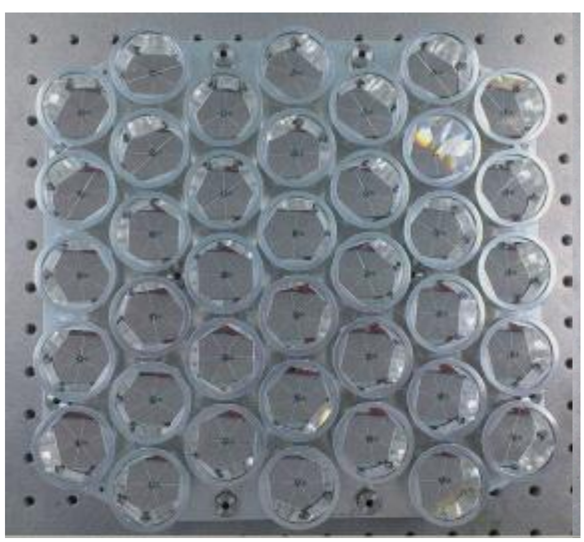
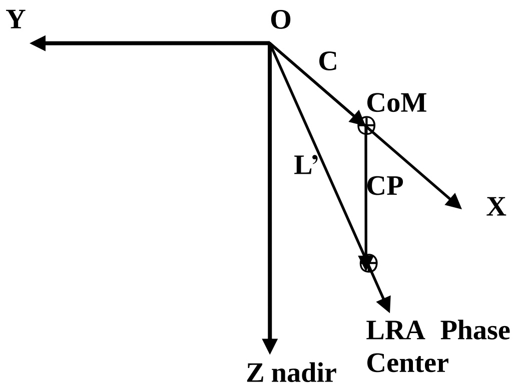


Fig.2 LRA of Compass-MS1

The Position of the Compass-MS1 Laser Retro-Reflector Array Phase Center



O — Satellite Coordinate Origin

Z — Nadir, to the Earth's Center

X — Direction of Satellite Flight

Y — by right-hand rule

CoM — Satellite Center of Mass

LRA Phase Center —

Laser Retro-reflector-Array's Phase Center

Vector C is from the satellite coordinate origin to the satellite's center of mass (CoM).

Vector L is from the satellite coordinate origin to the mass center of the LRA containing 90 corner cubes.

C = (-10.1, -8.4, 1177.8) mm.

L = (602, -80.1, 2418.8) mm.

The plane of the front faces of the cubes is +16.0 mm in the Z direction from the LRA mass center.

The cubes' phase centers are -h×n in the Z direction from the plane of the cubes.

For the Compass-MS1 cubes, h = 23.3 mm, n = 1.461@532nm. So phase centers are - 34.0mm in Z.

So z-component of array phase center is (-34.0+16.0) = -18.0 mm from the LRA mass center.

Let L′ as the vector from the satellite coordinate origin to the phase center of the LRA. We have

L′= (602, -80.1, 2418.8-18.0) mm, i.e. L′= (602, -80.1, 2400.8) mm

Finally, the vector CP from the satellite center of mass to the phase center of the LRA is CP = L′—C

So CP= (602, -80.1, 2400.8) - (-10.1, -8.4, 1177.8) = (612.1, -71.7, 1223.0) in the satellite fixed frame.

Refractive Index and Dispersion:

Conditions: 22 °C, 760 mm Hg, N_2

Wavelength [Vacuum] [nm]	Refractive Index[2] n	Thermal Coefficient $\Delta n/\Delta T$[3] [ppm/C]
1128.950	1.448866	9.6
1014.260 n_t	1.450241	9.6
852.344 n_s	1.452463	9.7
706.714 n_r	1.455144	9.9
656.454 n_C	1.456364	9.9
632.990	1.457016	10.0
587.725 n_d	1.458461	10.1
546.227 n_e	1.460076	10.2
486.269 n_F	1.463123	10.4
435.957 n_g	1.466691	10.6
404.770 n_h	1.469615	10.8
365.119 n_i	1.474539	11.2
334.244	1.479764	11.6
312.657	1.484493	12.0
253.728	1.505522	13.9
228.872	1.521154	15.5
214.506	1.533722	17.0
206.266	1.542665	18.1
194.227	1.558918	20.3
184.950	1.575017	22.7

Polynomial Dispersion Equation Constants[1], 22 °C	
A_0	2.104025406E+00
A_1	-1.456000330E-04
A_2	-9.049135390E-03
A_3	8.801830992E-03
A_4	8.435237228E-05
A_5	1.681656789E-06
A_6	-1.675425449E-08
A_7	8.326602461E-10

Sellmeier Dispersion Equation Constants[2], 22 °C	
A_1	0.68374049400
A_2	0.42032361300
A_3	0.58502748000
B_1	0.00460352869
B_2	0.01339688560
B_3	64.49327320000

$\Delta n/\Delta T$ Dispersion Equation Constants[3], 20-25 °C	
C_0	9.390590
C_1	0.235290
C_2	-1.318560E-03
C_3	3.028870E-04

Other Optical Properties	
nF'-nC'	0.006797
Stress Coefficient	35.0 nm/cm MPa
Abbe Constants:	
V_e	67.6
V_d	67.8

*1 Polynomial Equation: $n^2 = A_0 + A_1\lambda^4 + A_2\lambda^2 + A_3\lambda^{-2} + A_4\lambda^{-4} + A_5\lambda^{-6} + A_6\lambda^{-8} + A_7\lambda^{-10}$ with λ in μm
*2 Sellmeier Equation: $n^2-1 = A_1\lambda^2/(\lambda^2 - B_1) + A_2\lambda^2/(\lambda^2 - B_2) + A_3\lambda^2/(\lambda^2 - B_3)$ with λ in μm
*3 $\Delta n/\Delta T$ Equation: $\Delta n/\Delta T$ [ppm/C] = $C_0 + C_1\lambda^{-2} + C_2\lambda^{-4} + C_3\lambda^{-6}$ with λ in μm
The above dispersion equations for SiO_2 were fit to the refractive indices of 20 wavelengths from 1129 nm to 185 nm.