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:

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Array type (spherical, hexagonal, planar, etc.), to include a diagram or photograph:

Planar, 60 CCR

Array manufacturer:

Institute for Precision Instrument Engineering, Russian Federation

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

n/a

The LRA design and/or type of cubes was previously used on the following missions:

Glonass-729 (launched on 25/12/2008)

Glonass-736, Glonass-737, Glonass-738 (launched on 02/09/2010)

For accurate orbital analysis it is essential that full information is available in order that a model of 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 fixed reference frame with respect to the satellite's mass center. In practice this means that the following parameters must be available at mm accuracy or better:

The 3-D location (possibly time-dependent) of the satellite's mass center relative to a satellite-based origin:

Updates to the centre of mass will be provided by Prediction Centre.

CoM will be around x = 0.250 m, y = -0.013 m, z = 0.561 m

The 3-D location of the phase center of the LRA relative to a satellite-based origin:

x = -0.7030 m, y = -0.0275 m, z = 1.1175 m

However, in order to achieve the above if it is not directly specified (the ideal case) by the satellite manufacturer, and as an independent check, the following information must be supplied prior to launch:

The position and orientation of the LRA reference point (LRA mass-center or marker on LRA assembly) relative to a satellite-based origin:

Not needed, manufacturer provided the CoP

The position (XYZ) of either the vertex or the center of the front face of each corner cube within the LRA assembly, with respect to the LRA reference point and including information of amount of recession of front faces of cubes:

The orientation of each cube within the LRA assembly (three angles for each cube):

Parallel to the LRA plate, random rotation perpendicular to plate

The shape and size of each corner cube, especially the height:

height 19.1 mm, diameter 28.2 mm (aperture)

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

Fused Silica KУ1

The refractive index of the cube material, as a function of wavelength λ (micron):

n=1.461 for 532 nm

Dihedral angle offset(s) and manufacturing tolerance:

Nominal offset is zero. Manufacturing tolerance is 0.80 arcsec

Radius of curvature of front surfaces of cubes, if applicable:

n/a

Flatness of cubes' surfaces (as a fraction of wavelength):

n/a

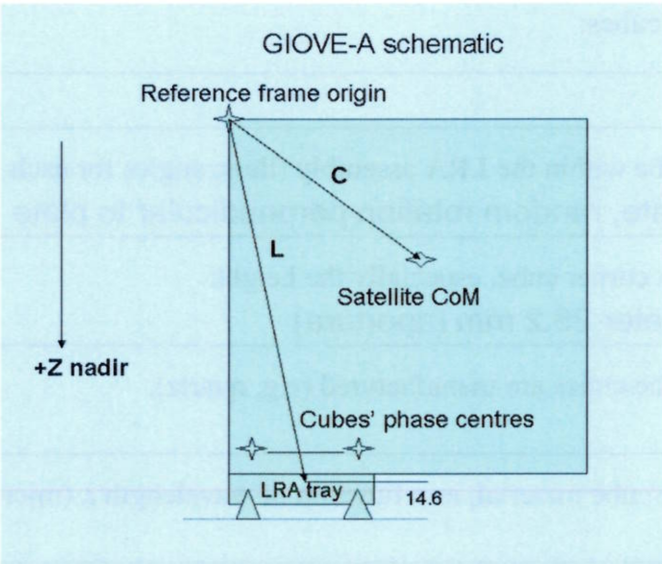
Whether or not the cubes are coated and with what material:

Reflective surface uncoated, no anti-reflection coating on front

Other Comments:

None

An example of the metric information for the array position that should be supplied is given schematically below for the LRA on the GIOVE-A satellite. Given the positions and characteristics of the cubes within the LRA tray, it is possible to compute the location of the array phase center. Then given the **C** and **L** vectors it is straightforward to calculate the vector from the satellite's center of mass (CoM) in a spacecraft-fixed frame to the LRA phase center. Further analysis to derive the array far-field diffraction patterns will be possible using the information given above.



A good example of a well-specified LRA is that prepared by GFZ for the CHAMP mission in the *paper "The Retro-Reflector for the CHAMP Satellite: Final Design and Realization", which is* available on the ILRS Web site at *http://ilrs.gsfc.nasa.gov/docs/rra_champ.pdf.*

The final and possibly most complex piece of information is a description (for an active satellite) of the satellite's attitude regime as a function of time, which must be supplied in some form by the operating agency. This algorithm will relate the spacecraft reference frame to, for example, an inertial frame such as J2000.

RETROREFLECTOR ARRAY REFERENCES

Two reports, both by David Arnold, are of particular interest in the design and analysis of laser retro-reflector arrays.

- Method of Calculating Retroreflector-array Transfer Functions, David A. Arnold, Smithsonian Astrophysical Observatory Special Report 382, 1979.
- *Retroreflector Array Transfer Functions,* David A. Arnold, ILRS Signal Processing Working Group, 2002. Paper available at *http://ilrs.gsfc.nasa.gov/docs/retro_transfer_functions.pdf.*