Session 3&4

Centre-of-mass correction information at the ILRS Website

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II. Key Issues
III. Your experiences?

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SLR Center-of-Mass (CoM) Measurement Correction Information

Initiated by Appleby and Torrence.

Several sats added/updated by Otsubo and Noll (as a task of ILRS Signal Processing WG).

International Laser Ranging Service

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SLR Center-of-Mass (CoM) Measurement Correction Information

The following table shows the components of the satellite body-fixed offset of the SLR array phase center (LRA offset: the blue vector in this SLR center of mass correction Concept Diagram) in the satellite's coordinate system. The total **SLR center of mass correction** (red vector) should be computed by using the LRA offset vector and the satellite Center of Mass (CoM) offset vector (green vector). The CoM offset may vary slightly with time, depending upon the use of propellant for satellite momentum dumps, satellite orbit maneuvers, antenna orientation changes, *et cetera*. The "location" of the LRA phase center may also vary; it is the locus of points from which the return came as a result of a particular satellite-station geometry and station characteristics (single or multiple photon, receiver type, *et cetera*).

Satellite	Size of Array	Number of Reflectors	Body Fixed Coordinates of Array Phase Center (mm)	Spacecraft Coordinate Definition	CoM Correction (mm) and details
ADEOS-1	35.6 cm edge hollow cube	1	?	?	
ADEOS-2	16 cm diameter hemisphere	9	(+5000, +1050, +500)	Y-axis anti-parallel with velocity, Z-axis away from nadir	details
Ajisai	214 cm diameter sphere	1,436	1028	sphere: radius of phase center of each cube	details
Beacon-C	Pyramidal array on nadir face	160	?	phase center of each cube	
BLITS	85.16 mm diameter sphere	1	(0, 0, 0)	origin at center of the single sphere	details
CHAMP	5cm diameter, 45 deg pyramid	4	(0, 0, 250)	Z-axis towards nadir	details
CryoSat-2	11.4 cm diameter, 0 or 57.5 deg pyramid	7	(1808.5, -935.0, -450.0) plus 15-25 mm for LRA details	X-axis 6° from the flight direction (nose-down), negative-Z-axis 6° from the nadir, Yaw steering (normal operation) applied so that Y-axis orthogonal to the satellite ground track	details
Envisat	20 cm diameter hemisphere	9	(-1058, +1359, -1183)	X-axis direction of satellite pitch, Z-axis away from nadir	details
ERS-2	20 cm diameter hemisphere	9	(1000, -710, -1010)	X-axis direction of satellite pitch, Z-axis away from nadir	
Etalon-1, -2	129.4 cm diameter sphere	2,134	614	sphere: radius of phase center of each cube	details
Galileo-101	33 mm diameter, 23.3 mm height	84	(1092, -34, 621)	X-axis negative to hemisphere containing the Sun, Y-axis along solar panel, Z-axis towards nadir	details
Galileo-102	33 mm diameter, 23.3 mm height	84	(1093, -34, 623)	X-axis negative to hemisphere containing the Sun, Y-axis along solar panel, Z-axis towards nadir	details
GFO-1	16 cm diameter hemisphere	9	(+182, +753, +599)	Y-axis anti-parallel with velocity, Z-axis away from nadir	details
GFZ-1	20 cm diameter sphere	60		sphere: radius of phase center of each cube	58 +/- 2
GIOVE-A	30x40 cm planar array	76	(-828, -655, +688)	X-axis negative to hemisphere containing the Sun, Y-axis along solar panel, Z-axis towards nadir, attitude details	details
GIOVE-B	30x30 cm planar array	67	(-804.3, +294.1, +1330.1)	X-axis negative to hemisphere containing the Sun, Y-axis along solar panel, Z-axis towards nadir, attitude details	details
GLONASS	120x120 cm planar array	396	(-1542, 0, 0)	X-axis away from nadir, Y-axis negative to hemisphere containing the Sun, Z-axis along solar panel	
GLONASS	66x66 cm planar array	132	(-1555, 0, 0)	X-axis away from nadir, Y-axis negative to hemisphere containing the Sun, Z-axis along solar panel	
GLONASS	66x66 cm planar array	124	(-1522, 0, 0)	X-axis away from nadir, Y-axis negative to hemisphere containing the Sun, Z-axis along solar panel	
GLONASS-95, -99, -100, -102, -109, -115	30x50 cm planar array	112	(-1874, -137, +3)	X-axis away from nadir, Y-axis negative to hemisphere containing the Sun, Z-axis along solar panel	details
GLONASS-125	annulus array	123			details
GPS-35	23.9x19.4 cm planar array	32	(862.6, -524.5, 669.5)	X-axis positive to hemisphere containing the Sun, Y-axis along solar panel, Z-axis towards nadir	details
GPS-36	23.9x19.4 cm planar array	32	(862.6, -524.5, 671.7)	X-axis positive to hemisphere containing the Sun, Y-axis along solar panel, Z-axis towards nadir	details
GRACE-A, -B	5cm diameter, 45 deg pyramid	4	(-600, -327.5, 217.8)	X-axis is the 'front', Z-axis towards nadir, Y-axis completes the orthogonal system	details
Gravity Probe B	Open hemisphere	9	(0, 0, -1820)	+Z-axis towards RA 343.26deg, DEC 16.84deg	details
ICESat	16 cm diameter hemisphere	9	(-1045, -4, 280) (plus 4.5 cm for the LRA)	X-axis towards satellite zenith, Y-axis along solar panel	details
Jason-1	hemisphere	9	(236, 598, 683)	X-axis in direction of velocity, Z-axis towards nadir	details
Jason-2	hemisphere	9	(213, 598, 683)	X-axis in direction of velocity, Z-axis towards nadir	details
LAGEOS-1	60 cm diameter sphere	426	258	sphere: radius of phase center of each cube	details
LAGEOS-2	60 cm diameter sphere	426	258	sphere: radius of phase center of each cube	details
LARES	36.4 cm diameter sphere	92	137.1	sphere: radius of phase center of each cube	details
Larets	20 cm diameter sphere	60	56.2	sphere: radius of phase center of each cube	details
LRE	quasi-spherical, 47x51 cm diameter	126		sphere: radius of phase center of each cube	210 details
Meteor-3M	spherical ball, 6 cm diameter	1	(+113, +475.7, +2101.5)	?	details
Starlette	24 cm diameter sphere	60		sphere: radius of phase center of each cube	75 details
Stella	24 cm diameter sphere	60		sphere: radius of phase center of each cube	75
TOPEX/Poseidon	150 cm diameter annulus	192	(+1079, +418, +827)	Center of annulus. X-axis in direction of velocity, Z-axis towards nadir	details
WESTPAC	24 cm diameter sphere	60	63.4	Radius of satellite through front face of the cubes (91mm)	details

http://ilrs.gsfc.nasa.gov/missions/spacecraft_parameters/center_of_mass.html

SLR Center-of-Mass (CoM) Measurement Correction Information

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Galileo-101	33 mm diameter,	84	(1092, -34, 621)	X-axis negative to hemisphere	details

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Ajisai

Jump to: Mission Objectives, Mission Instrumentation, Mission Parameters, Additional Information

Mission Photos:

Courtesy of JAXA

Mission Objectives:

Ajisai is Japanese for Hydrangea. Prior to launch, the satellite was called Experimental Geodetic Satellite (EGS). The Ajisai mission has two primary objectives. The first objective, which was short term, was testing of NASDA's (now JAXA) H-I, two-stage, launch vehicle. The second and primary long term objective was to determine the exact positions of the many isolated Japanese Islands. Ajisai can also be used for directional and photometric observations, using the mirrors equipped on the surface of satellite.

Mission Instrumentation:

Ajisai has the following instrumentation onboard:

Ajisai

RetroReflector Array (RRA) Characteristics:

The retro-reflector array (RRA) consists of 1436 cube corners. The RRA response function is available from NERC.

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Ajisai

Center of Mass Information:

ref: Otsubo and Appleby, "System-dependent centre-of-mass correction for spherical geodetic satellites" Journal of Geophysical Research, 108, B4, 2201, doi:10.1029/2002JB002209, 2003.

The *standard* Ajisai center-of-mass correction is 1010 mm.

correction for single photon systems

edit level	com (mm)
none	962
3.0	976
2.5	985
2.0	997

correction for C-SPAD (mm)

FWHM pulse width (ps)	edit level	ave. num detected photons			
		0.1	1	10	100
1	3.0	977	990	1020	1023
	2.5	985	996	1020	1023
	2.0	997	1004	1021	1023
100	3.0	976	989	1012	1016
	2.5	985	995	1013	1016
	2.0	997	1002	1013	1016

correction for leading-edge-half

FWHM pulse width (ps)	com (mm)

How we add a satellite

1. **Read the mission request form.**

2. **Contact the mission people for the missing/unclear info. ← not always easy (ex. CryoSat-2)**

3. **Compute the CoM correction if necessary. ← hard/laborious work (ex. LARES)**

4. **Revise the webpage.**

Mission Request Form Section III

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: ______________________________

Address: ______________________________

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

____

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Array manufacturer:

____

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

____

____

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

____

____

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:

____

____

Mission Request Form Section III

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

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:

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):

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

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

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

Dihedral angle offset(s) and manufacturing tolerance:

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

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

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

Mission Request Form
Section III

Other Comments:

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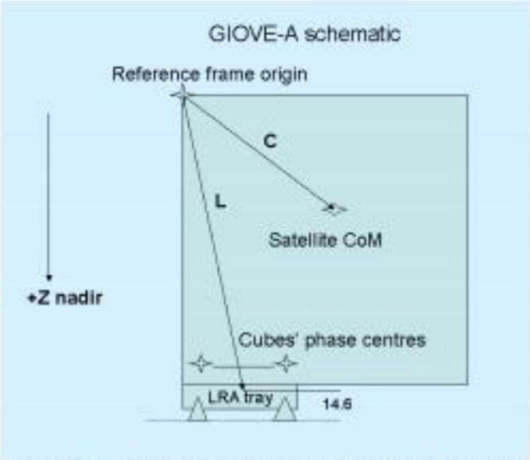
An example of the metric information for the array position that should be supplied is given schematically below for the LRA on the GIOVE-A satellite. Given the positions and characteristics of the cubes within the LRA tray, it is possible to compute the location of the array phase center. Then given 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

Open Issue 1: Mission Request Form

- Not everyone answers all the questions ("TBD").
- Identical or almost identical satellite case (ex. GLONASS).
  - Do they have to submit the form?

"Phase center of the LRA"

- Not easy to achieve at the 1-mm level.
- Who should be responsible?
- Orientation dependent, wavelength dependent, …

- Lack of the definition of the satellite-body-fixed frame.

Not a sufficient answer column given (ex. XYZ for all retros).

Key: How precise do they (we) want its orbit? m? cm?

Open Issue 2: Webpage

Have you looked at it? Did you find it useful? (Worth maintaining?)

How should we handle both spherical & non-spherical targets?

- **Possibly in a separate chart?**

Coordinate definition: sometimes very complicated. (ex. CryoSat-2)

How should we cope with time-varying attitude/CoM?

(Same) Key: How precise do they (we) want its orbit?

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