ILRS SLR MISSION SUPPORT REQUEST FORM (June 2011)

SECTION I: MISSION INFORMATION:

General Information:

Satellite Name: Galileo-201 (SIC=7201) and Galileo-202 (SIC=7202)

Satellite Host Organization: European Space Agency

Web Address: http://www.esa.int/esaNA/index.html

Contact Information:

Primary Technical Contact Information:

Name: Daniel Navarro-Reyes

Address: ESA/ESTEC (NAV-NMS) Ta-007

Keplerlaan 1 - P.O. Box 299 2200 AG Noordwijk, The Netherlands

Phone No.: +31 71 565 8313

Fax No.: +31 71 565 4369

E-mail Address: Daniel.Navarro-Reyes@ESA.int

Alternate Technical Contact Information:

Name: Francisco Gonzalez

Address: ESA/ESTEC (TEC-ETC) Ta-005

Keplerlaan 1 - P.O. Box 299; 2200 AG Noordwijk, The Netherlands

Phone No.: +31 71 565 3961

Fax No.: +31 71 565 4369

E-mail Address: Francisco.Gonzalez@ESA.int

Primary Science Contact Information:

Name: Erik Schoenemann

Address: ESA/ESOC (HSO-GN) A135

Robert-Bosch-Str. 5; 64293 Darmstadt, Germany

Phone No.: +49 6151 90 2653

Fax No.: +49 6151 90 2271

E-mail Address: Erik.Schoenemann@esa.int

Alternate Science Contact Information:

Name: Rene Zandbergen

Address: ESA/ESOC (HSO-GN) A133

Robert-Bosch-Str. 5; 64293 Darmstadt, Germany

Phone No.: +49 6151 90 2236

Fax No.: +49 6151 90 2271

E-mail Address: Rene.Zandbergen@esa.int

Mission Specifics:

Scientific or Engineering Objectives of Mission:

Global Navigation Satellite System

Satellite Laser Ranging (SLR) Role of Mission:

Precise characterisation of the performance of the on-board atomic clocks, of the antenna infrastructure, of the signal properties. Support to the characterisation of the satellite properties (and their modelling) relevant to the navigation. Support to Geodesy services.

Anticipated Launch Date: 21 August 2014

Expected Mission Duration: 12 years

Orbital Accuracy Required: 10 cm

Anticipated Orbital Parameters:

Altitude: 23220 km

Inclination: 56 deg +/- 2 deg

Eccentricity: less than 0.001

Orbital Period: 14.08 hours

Frequency of Orbital Maneuvers: Once nominal slot is reached, every 5-7 years.

Mission Timeline: Launch into MEO, drift to nominal slot, IOT, start of service (about T0+3 months), disposal in graveyard orbit (T0+12 years)

Tracking Requirements:

Tracking Schedule: Per campaign request and available for geodetic applications

Spatial Coverage: Global

Temporal Coverage: Usually 10 days (17 revolutions)

Operations Requirements:

Prediction Center: ESA/ESOC Navigation Office

Prediction Technical Contact Information:

Name: Cristina Garcia Serrano

Address: ESA/ESOC (HSO-GN) E77

Robert-Bosch-Str. 5; 64293 Darmstadt, Germany

Phone No.: +49-6151-90-2384

Fax No.: +49-6151-90-3412

E-mail Address: ilrs-esoc@esa.int

Priority of SLR for POD: High

Other Sources of POD (GPS, Doppler, etc.):

Galileo Navigation signal

Normal Point Time Span (sec): ILRS standard for tracking of GNSS satellites

Tracking Network Required (Full/NASA/EUROLAS/WPLTN/Mission Specific):

Full

SECTION II: TRACKING RESTRICTIONS:

Several types of tracking restrictions have been required during some satellite missions. See *http://ilrs.gsfc.nasa.gov/satellite_missions/restricted.html* for a complete discussion.

1) Elevation restrictions: Certain satellites have a risk of possible damage when ranged near the zenith. Therefore a mission may want to set an elevation (in degrees) above which a station may not range to the satellite.
2) Go/No-go restrictions: There are situations when on-board detectors on certain satellites are vulnerable to damaged by intense laser irradiation. These situations could include safe hold position or maneuvers. A small ASCII file is kept on a computer controlled by the satellite's mission which includes various information and the literal "go" or "nogo" to indicate whether it is safe to range to the spacecraft. Stations access this file by ftp every 5-15 minutes (as specified by the mission) and do not range when the flag file is set to "nogo" or when the internet connection prevents reading the file.
3) Segment restrictions: Certain satellites can allow ranging only during certain parts of the pass as seen from the ground. These missions provide station-dependent files with lists of start and stop times for ranging during each pass.
4) Power limits: There are certain missions for which the laser transmit power must always be restricted to prevent detector damage. This requires setting laser power and beam divergence at the ranging station before and after each pass. While the above restrictions are controlled by software, this restriction is often controlled manually.

Many ILRS stations support some or all of these tracking restrictions. See xxx for the current list. You may wish to work through the ILRS with the stations to test their compliance with your restrictions or to encourage additional stations that are critical to your mission to implement them.

The following information gives the ILRS a better idea of the mission's restrictions. Be aware that once predictions are provided to the stations, there is no guarantee that forgotten restrictions can be immediately enforced.

Can detector(s) or other equipment on the spacecraft be damaged or confused by excessive irradiation, particularly in any one of these wavelengths (532nm, 1064nm, 846nm, or 423nm)?

No

Are there times when the LRAs will not be accessible from the ground?

no

(If so, go/nogo or segmentation files might be used to avoid ranging an LRA that is not accessible.)

Is there a need for an altitude tracking restriction? no What altitude (degrees)? n/a

Is there a need for a go/no-go tracking restriction? no

For what reason(s)?

n/a

Is there a need for a pass segmentation restriction? no

For what reason(s)?

n/a

Is there a need for a laser power restriction? no

Under what circumstances?

n/a

What power level (mW/cm^2)? n/a

Is manual control of transmit power acceptable? n/a

For ILRS stations to range to satellites with restrictions, the mission sponsor must agree to the following statement:

"The mission sponsor agrees not to make any claims against the station or station contractors or subcontractors, or their respective employees for any damage arising from these ranging activities, whether such damage is caused by negligence or otherwise, except in the case of willful misconduct."

Please initial here to express agreement: ____________

Other comments on tracking restrictions:

None

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: Alessandra Ostillio

Address: ESA/ESTEC (TEC-ETP) Ta103

Keplerlaan 1 - P.O. Box 299 2200 AG Noordwijk, The Netherlands

Phone No.: +31 71 565 3468

Fax No.: +31 71 565 3411

E-mail Address: Alessandra.Ostillio@esa.int

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 КУ1

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

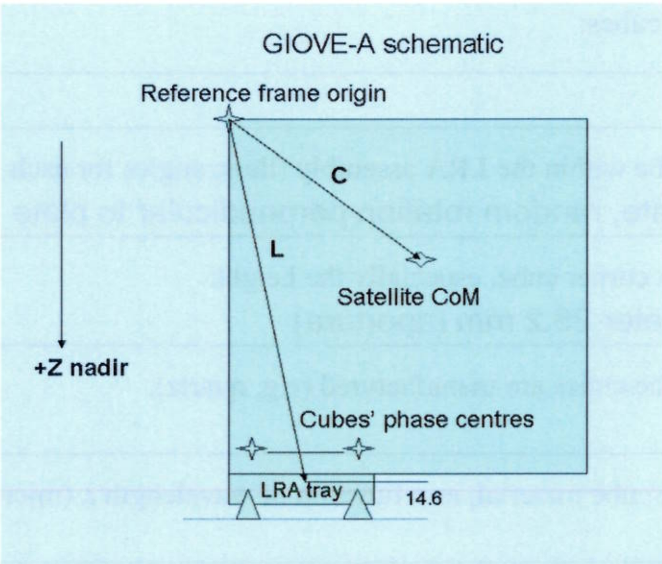
Whether or not the cubes are coated and with what material:

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.*

SECTION IV: MISSION CONCURRENCE

As an authorized representative of the Galileo mission, I hereby request and authorize the ILRS to track the satellite described in this document.

Name (print): Javier Benedicto Date 18/7/2016

Signature: [signature]

Position: Project Manager

Send form to:

ILRS Central Bureau
c/o Carey Noll
NASA GSFC
Code 690
Greenbelt, MD 20771
USA
301-614-6542 (Voice)
301-614-6015 (Fax)
Carey.Noll@nasa.gov