ILRS SLR MISSION SUPPORT REQUEST FORM-March 2014

SECTION I: MISSION INFORMATION:

General Information:

Satellite Name: Indian Regional Navigation Satellite System- IRNSS-1B

Satellite Host Organization: Indian Space Research Organization(ISRO)

Web Address: http://www.isro.gov.in ; http://www.istrac.gov.in

Contact Information:

Primary Technical Contact Information:

Name: V. Jayaraman, Associate Project Director, IRNSS Ground Segment,

Address: Plot No:12 &13, 3rd Main, 2nd Phase, Peenya Industrial Area,
Bangalore-560058, Karnataka State, INDIA

Phone No.: +91-80-28094530

Fax No.: +91-80-28094203

E-mail Address: jayaram@istrac.org; jayaram2k@gmail.com

Alternate Technical Contact Information:

Name: L. Srinivasan, Project Director, GSN-SNP,

Address: Plot No:12 &13, 3rd Main, 2nd Phase, Peenya Industrial Area,
Bangalore-560058, Karnataka State, INDIA

Phone No.: +91-80-28094554

Fax No.: +91-80-28094203

E-mail Address: lsvasan@istrac.org;

Primary Science Contact Information:

Name: S. C. Ratnakara, Dy Project Director, IRNSS Navigation Software,

Address: ISRO Satellite Center, Airport Road, Vimanapura Post,
Bangalore-560017, Karnataka State, INDIA

Phone No.: +91-80-25084331

Fax No.: +91-80-25084332

E-mail Address: ratnakar@isac.gov.in

Alternate Science Contact Information:

Name: A.S.Ganeshan, Project Director, Satellite Navigation Program,

Address: ISRO Satellite Center, Airport Road, Vimanapura Post,
Bangalore-560017, Karnataka State, INDIA

Phone No.: +91-80-25084386

Fax No.: +91-80-25084275

E-mail Address: asganesh@isac.gov.in

Mission Specifics:

Scientific or Engineering Objectives of Mission:

ISRO plans to carry out the experiments on satellite based navigation techniques using IRNSS and estimation of IRNSS Satellites orbits and clocks on real time basis. In this experiment ISRO is planned to study the techniques on " Onboard atomic clock performance evaluation", Clock Synchronisation technique between satellite and ground station, ranging error estimation techniques and precise orbit determination techniques for Geo-stationary and Geo-synchronous satellite missions.

Satellite Laser Ranging (SLR) Role of Mission:

To determine the orbit of IRNSS precisely and also used for evaluation of orbit determination accuracy using navigation data. Also to evaluate time synchronisation between ground clock and onboard clocks and to estabilish the SLR tracking techniques for Geo-stationary and Geo-synchronous satellites. Also the SLR tracking will be used to supplement and also to calibrate the ISRO CDMA ranging systems.

Anticipated Launch Date: 04th April 2014

Expected Mission Duration: 12 years

Orbital Accuracy Required: 5mm or better

Anticipated Orbital Parameters:

Altitude: 42164 Km

Inclination: 31 degrees

Eccentricity: 0.0002

Orbital Period: 24 hrs(86400secs)

Frequency of Orbital Maneuvers: 21 days

Mission Timeline: To be decided later.

Tracking Requirements:

Tracking Schedule: SLR tracking is required after 40 days from launch or as soon orbital parking slot reached. Support required for 4hours each day for total of 30 days

Spatial Coverage: The Asiatic continent and Indian Ocean Area

Temporal Coverage: All times

Operations Requirements:

Prediction Center: ISRO Telemetry Tracking and Command Network

Prediction Technical Contact Information:

Name: T.Subrmanya Ganesh, Deputy Project Director-IRNWT, IRNSS Ground Segment,

Address: Plot No:12 &13, 3rd Main, 2nd Phase, Peenya Industrial Area,
Bangalore-560058, Karnataka State, INDIA

Phone No.: +91-80-28094216

Fax No.: +91-80-28094203

E-mail Address: ganesht@istrac.org;

Priority of SLR for POD: Primary

Other Sources of POD (GPS, Doppler, etc.):
IRNSS navigation message, CDMA based orbit determination

Normal Point Time Span (sec): 300 sec

Tracking Network Required (Full/NASA/EUROLAS/WPLTN/Mission Specific):
SLR stations over Asian region, European region and African Continents

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)?

Currently there are no such restrictions envisaged. However exact details will be declared two months prior to satellite launch.

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

As IRNSS is a Geo-stationary/Geo-synchronous missions, this may not be applicable. Detailed study will be done. However exact details will be declared two months prior to satellite launch..

(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? NA What altitude (degrees)? NA

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

For what reason(s)?

NA

Is there a need for a pass segmentation restriction? NA

For what reason(s)?

NA

Is there a need for a laser power restriction? NA

Under what circumstances?

NA

What power level (mW/cm^2)? NA

Is manual control of transmit power acceptable? To be decided later

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: A.S.Ganeshan

Other comments on tracking restrictions:

Exact details on tracking restrictions will be declared two months prior to satellite launch.

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: M. Nageswara Rao, Project Director,IRNSS Space Segment,

Address: ISRO Satellite Center, Airport Road, Vimanapura Post,

Bangalore-560017, Karnataka State, INDIA

Phone No.: +91-80-25082662

Fax No.: +91-80-25084275

E-mail Address: mnrao@isac.gov.in

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

Hexagon Array

Array manufacturer:

LEOS, ISRO, Bangalore, INDIA

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

FFDP(Far field diffraction pattern) measurements carried out. Reference details at present not available, will be provided later, if required.

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

First of its kind

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:

Details will be provided 2 months prior to launch.

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

Details will be provided 2 months prior to launch.

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:

Details will be provided 2 months prior to launch.

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:

Details will be provided 2 months prior to launch.

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

Details will be provided 2 months prior to launch.

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

29.70 mm height clear aperture Dia:38mm

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

Fused Quartz - Suprasil Grade

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

Material Data sheet enclosed

Dihedral angle offset(s) and manufacturing tolerance:

0 deg +/- 0.5 arc secs

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

Nil (flat surface)

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

lamda/10 or better

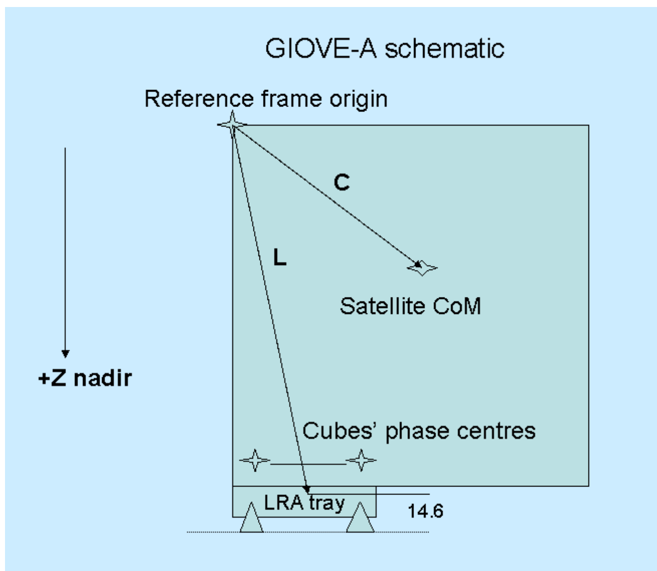
Whether or not the cubes are coated and with what material:

No coating

Other Comments:

Further details, if there are any will be provided 2 months prior to launch.

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 IRNSS-1B mission, I hereby request and authorize the ILRS to track the satellite described in this document.

Name (print) : GANESHAN A.S date 08-November 2013

Signature

ए. एस. गणेशन / A.S. GANESHAN
कार्यक्रम निदेशक, उपग्रह नैसंचालन कार्यक्रम
Programme Director, Satellite Navigation Programme

Position: Programme Director, Satellite Navigation Programme

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

Refractive index of SUPRASIL at selected laser wavelengths

Laser	Wavelength nm	Refractive index
ArF	193	1.56077
KrF	248	1.50855
4 × Nd:YAG	266	1.49968
XeCl	308	1.48564
HeCd	325	1.48164
N_2	337	1.47921
XeF	351	1.47672
3 × Nd:YAG	355	1.47607
N_2	427	1.46745
HeCd	441.6	1.46622
Ar	488	1.46301
Ar	514.5	1.46156
2 × Nd:YAG	532	1.46071
HeNe	632.8	1.45702
Kr	447.1	1.45661
Ruby	694.3	1.45542
Kr	752.5	1.45419
GaAs	905	1.45168
Nd:YAG	1064	1.44963
HeNe	1153	1.44859
Nd:YAG	1319	1.44670

Relative temperature coefficients of the refractive index in $10^{-6}\,K^{-1}$

Wavelength	Suprasil		Homosil/Herasil/Infrasil/HOQ	
nm	0...20°C	20...40°C	0...20°C	20...40°C
237.8	14.6	14.9	15.2	15.3
365.0	11.0	11.2	11.5	11.6
546.1	9.9	10.1	10.6	10.7
587.6	9.8	10.0	10.5	10.6
643.8	9.6	9.8	10.4	10.5

Abbe constant

$\nu_d = \frac{n_d - 1}{n_F - n_C}$	67.8 ± 0.5	67.6 ± 0.5

Birefringence constant

$\frac{nm}{cm \cdot bar}$	3.54 ± 0.05	3.61 ± 0.05

Refractive index and dispersion as a function of wavelength