Reviving Laser Ranging to Satellites Station at Kavalur, India

K. Elango, Senior Scientist (Retired), Manager, PRARE, SLR and GPS Systems, Deputy Project Director, IRNSS, Indian Space Research Organisation (ISRO), H-19, Tamil Nadu Housing Board Colony ,Rasipuram Post, Namakkal District, TN-637408, INDIA. e-mail: ***elango*.kattimuthu@gmail.com**

Abstract

A Satellite Tracking and Ranging Station (STARS) was established and operated by Indian Space Research Organisation (ISRO) in collaboration with Academy of Sciences (AS-USSR) at Kavalur, in Jawadi hills near Vaniyambadi, Tamil Nadu, India. The Campus is owned and maintained by Indian Institute of Astrophysics (IIA). This station was part of Interkosmos Network and was in operation from 1976 -1985 with about 125 cloud/rain-free nights. The performance and results of this satellite ranging laser station were presented in the 4th International Workshop on laser ranging conducted at Austin, Texas, USA during Oct. 12-16, 1981.The station was first generation supported by the Interkosmos network and ISRO. This paper briefs the performance of the Kavalur station, its weather condition supporting for geodetic activities, geographic location, free from industry pollution, away from city lights, co-located with array of several astronomical telescopes with various apertures by IIA, ISRO initiatives for space geodesy, closer to the earth's equator for covering both northern and southern hemispheres with equal ease etc. ISRO has currently seven navigation satellites with laser payload in Geo- orbit. There is a laser station network gap in the Indian Ocean. A resolution was made in the 11th International workshop conducted in Deggen-dorf, Germany in September, 1998 in this connection to fill the geographic gap. By reviving Kavalur with a new laser ranging station, will fill the long pending geographic gap in Indian Ocean for geodetic purposes and can be made use of this station to track international satellites. This will also supplement the upcoming two laser Ranging stations by ISRO.

Introduction

Government of India has approved in July 1975 the collaboration between Indian Space Research Organisation (ISRO) and Academy of Sciences - USSR (AS-USSR) in establishing a laser ranging station for scientific purposes at Kavalur, in India, as part of Inter-Cosmos Network **(**Hungary, East Germany, Poland, Czechoslovakia**,** Soviet Union and India). This station was named as Satellite Tracking and Ranging Station (STARS) and having first generation laser system, Optical tracking Camera AFU-75, Timing equipment and accessories and was operational by October 1976. STARS was located in the campus of Indian Institute of Astrophysics (IIA), named as Vainu Bappu Observatory (VBO) after the founder of IIA.

Weather Conditions at Kavalur

Peninsular India is usually hit by two monsoons in a year, the south-west monsoon starting around the beginning of June and the North-East monsoon which settles around the end of October. The peak Night observing season is January – April/May. Kavalur is located about 175 Km South-East of Bangalore and about 200 Km South-West of Chennai and about 12 km away from the nearest town Alangayam.

The coordinates of Kavalur are:
Latitude:12 deg. 34' N
Longitude: 78 deg. .49'E
Height: 700m (2297 feet) above MSL

Kavalur had the ideal features namely,
(1) It is far from industrial pollution and busy city activities;
(2) It had about 150 days of clear sky during nights in a year which is the maximum in South India;
(3) It was centrally located between Australia and South Africa and best suited to study both the constellations in the northern and southern hemispheres; and
(4) Finally, the altitude of 700 metres above sea level was very appropriate for astronomical studies and research.

Today IIA has an array of telescopes of various apertures ranging from 15 inches (38 cm) to 90 inches (230 cm)

Operational experience on laser ranging to satellites
The Station has tracked satellites equipped with retro reflectors for more than a decade, Accurate Time synchronization of Cesium Atomic clocks using Symphonie satellite, locating the positions of geostationary satellites using AFU-75 Camera, Improved the tracking capability of Laser Radar and Photographic Camera by incorporating three stage Image Intensifier and bring the image to a TV monitor, providing calibration support to other systems etc. This station was operational for one decade (1976 – 1985).

Satellites tracked
The following Satellites were tracked by the Kavalur Station:

1. Beacon - B (Beacon Explorer) (10-10-1964 launch)
2 .Beacon - C (Beacon Explorer)
3. GEOS-A (Geodetic Earth Orbiting Satellite)
4. GEOS-B (Geodetic Earth Orbiting Satellite)
5. GEOS-C (Geodynamics Experimental Ocean Satellite)
6. Bulgaria-1300
7. STARLETTE (The Geodetic Satellite –July 1, 1974)

Visit of Mr Rajiv Gandhi, Prime Minister of India to Kavalur
Mr. Rajiv Gandhi, the Prime minister of India visited STARS, Kavalur on 6th January 1986 and seen the Red Laser shots to the test targets and satellite, optical tracking systems and facilities and appreciated the scientists and engineers for the scientific work and tasks carried out..

Interkosmos Laser Radar at Kavalur

Interkosmos AFU-75 Camera

International laser experts visited

Following are some of the International Scientists/experts visited Kavalur Station in connection with scientific activities:

1. Prof. AG Massevitch, AS-USSR
2. Prof Tatevian, AS-USSR
3. Dr Kasmir Lapuska, Latvian State University, Riga
4. DR. Micheal R. Pearlman, SAO, USA
5. Shillack S, Polish Academy of Sciences, Poland
6. Abele.M, , Latvian State University, Riga
7. Prof Karel Hamal, Czech Technical University in Prague
8. Kielek,W, Warsaw University
9. Istanbul Kardos

Support Services provided to other systems by STARS

Kavalur optical tracking station has provided Time synchronization to other atomic frequency standards, locating geostationary satellites' position, calibration support to other tracking systems, simultaneous observations with other Interkosmos networks etc.

The INSAT-1A satellite lost the earth lock because of an "unanticipated moon interference" on September 4 and was finally deactivated on September 6, 1982 The Satellite Tracking and Ranging Station (STARS) at Kavalur, Tamil Nadu, was, however, asked to hunt up the satellite.

Different Space techniques planned at Bangalore/Kavalur)

The following Space Geodetic Techniques were planned at ISTRAC Campus, Bangalore:

1. Satellite Laser Ranging
2. Precise Range and Range rate Equipment (PRARE)
3. Global Positioning System (GPS)
4. Doppler Orbitography and Radiopositiong Integrated by Satellites (DORIS)- Not realized
5. Very Long Base Interferometry (VLBI) – not yet realized
6. Transportable Laser Ranging Station (TLRS) – Not Realized)
7. Transportable Integrated Geodetic Observatory (TIGO)- Not Realized)

(i) SAO (Smithsonian Astrophysical Observatory) – ISRO, MOU in 1979 -1983

Initially, discussions on the Agreement between ISRO (Indian Space Research Organization) and SAO **(Smithsonian Astrophysical Observatory)/GSFC in establishing a Laser Station and Satellite Geodesy** in India have taken place.

(ii) GeoForchung Zentrum (GFZ) – ISRO, MOU in 1990s

Indian Space Research Organisation (ISRO) and GeoForchung Zentrum (GFZ), Germany, entered into a MOU on establishing a Precise Range and Range rate Equipment (PRARE) at ISTRAC Campus, Bangalore in 1990s for scientific purpose. This unit was operational in 1994 and was tracking satellites with PRARE payload like Meteor, ERS-1 etc. Subsequently, the first P-code Global Positioning System (GPS) was installed at Bangalore to elevated Bangalore in the International Geodetic map (DORIS was also planned but could not be installed for technical reasons).

(iii) GSFC/NASA – ISRO MOU in 1998

Technical discussions were held couple of rounds both at ISRO, Bangalore and GSFC/NASA, Washington and site selection was carried out by NASA Scientists during February-March 1998 to shift TLRS-4 (Transportable Laser Ranging Station) from NASA site but could not materialise.

(iv) Visits by BKG, Germany – 1999

Site survey was carried out by the BKG (Federal Agency for Cartography and Geodesy), Germany in 1999 to locate their Geodetic Observatory TIGO (Transportable Integrated Geodetic Observatory), but placed Bangalore as their second choice and first moved to Chile.

(v) Indian Regional Navigational Satellite System (IRNSS)

Laser payloads, CCRR were planned to incorporate in the navigation satellites and operationalized in 2013.
Laser tracking stations identified in two locations in India are going to be operational shortly.

Discussions with BKG, Germany for TIGO in India

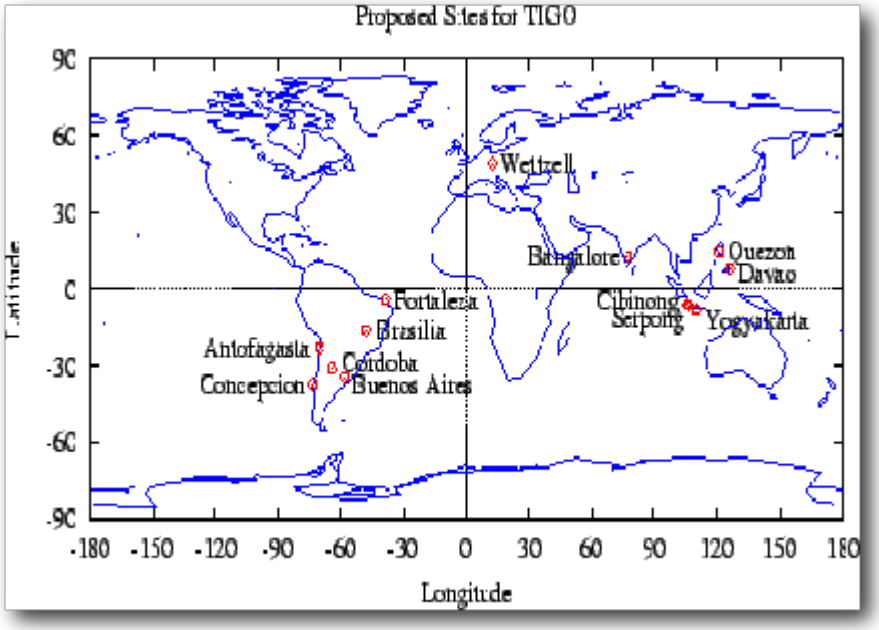
Transportable Integrated Geodetic Observatory (T I G O)

- Based on the announcement of opportunity from Federal Office of Cartography and Geodesy (BKG), Germany, for locating TIGO, a letter of intent was submitted to BKG in 1999.

- This intent includes details on site, infrastructure, partnership, staff, use of TIGO data, period of operation and Indian interest on the proposal.

- This TIGO mobile Observatory includes three mobile containers of systems containing satellite laser ranging, Very long baseline Interferometer (VLBI), three number of Global positioning System (GPS), German based Precise Range and Range rate Equipment (PRARE), Timing system with Cesium Frequency standards & Hydrogen Maser etc.

- A presentation on the site selection and other aspects was made to the BKG team, Germany, led by Dr Wolfgang Schluter, team leader of German Geodesy & Cartography Organisation (BKG), Germany at Bangalore (close to Kavalur) when visited in December 1999 and the team has approved Bangalore as the alternate site for locating TIGO in January 2000.



In June 1999 the TIGO components had passed the tests successfully, which allowed for an international advertising about TIGO. Applications from Brazil, Argentina, Chile**, India**, Philippine and Indonesia demonstrated interest to receive TIGO. In the end of 1999 the 12 proposed sites in the six countries had been inspected.

Discussions with NASA for installing a laser station at Bangalore (close to Kavalur)

A committee was formed and Mr Elango was leading the committee for preparing and discussing the feasibility of locating a laser system in India for tracking Indian satellite. Parallelly, dialogues were initiated for providing laser pay loads to Indian future satellites

A presentation was made on “The feasibility of locating Satellite Laser Ranging System in Bangalore, India” to the NASA expert team who visited Bangalore for identifying a site for locating their laser system,TLRS-4, in India and preliminary dialogues were initiated with the NASA expert team in Feb. 1998.

NASA team discussed with the ISRO team, approved the Bangalore site for locating one of the NASA's laser station (Transportable Laser Ranging Station - TLRS-4) and the MOU was prepared accordingly in March 1998.

As a Project manager for Indian Remote Sensing Satellite (IRS P-5/TES – Technology Experimental Satellite), he was responsible for the retro-reflector pay-load on-board to IRS-P5/TES. Support for the global SLR network stations was initiated with ILRS Central Bureau. A report on Laser Retro-reflector Array (LARA) to Indian Satellites was generated and presentation was made to the committee.

Shri Elango has presented a paper "Laser Retro-reflector Array (LARA)" at the 13th International workshop on Laser Ranging at Washington D.C, USA in October 2002.

Participation of ISRO Scientists in laser workshops/ILRS/WPLTN

The following presentations/participations were made by ISRO scientists during the international workshops/conferences:

1. **First SLR Workshop paper from India**
   "***Performance and Results of Satellite Ranging Laser Station at Kavalur*, India in 1980-81**",
   Dixit, P. S., Rao, P. **K., Elango** .K. Gopalakrishnan, K., Rao, K. N., Schillak, S., Kielek, W., Abele, H.,
   Presented in the 4th International Workshop on Laser Ranging Instrumentation held in during October 12 – 16, Austin, Texas-78712, USA

2. "**Site Selection Criteria for locating a laser station at ISTRAC Campus, Bangalore,India"**
   K.Elango, P.Soma, K.Ramesh Chandra & S.Rangarajan, ISTRAC/ISRO,Bangalore
   Presented during the 11th International workshop on laser Ranging held at Deggondorf, Germany.

3. **"Laser Retro reflector Array (LARA) for IRS Mission (Poster Summary)",**
   K.Elango, P.Soma, M.Pitchaimani, S.K.Shivakumar Presentation in the13th International Workshop on Laser Ranging, Washington, DC, USA, October 7-11, 2002.

4. **"Indian Interest on SLR"**
   Elango, K., P. Soma, S.K. Shivakumar, submitted to 14th International Laser Ranging Workshop, San Fernando, Spain, June 7-11, 2004.

5. **"Laser Ranging to Indian Regional Navigational Satellite System (IRNSS)-(A Proposal)"**
   K. Elango, P. Soma & S.K. Shivakumar submitted to 15th International Laser Ranging Workshop, Canberra 15-21, October 2006.

6. **WPLTN (Western Pacific Laser Tracking Network)**
   As a member, Participated in the WPLTN splinter meeting held during the 13th International workshop on laser ranging at Washington D.C. in 2002 and provided inputs in the subsequent WPLTN meetings

7. **"ISRO Initiatives for Space Geodesy and Geodynamics in India"**
   K. Elango, P. Soma, K. Rameshchandra, S. Rangarajan presented during the conference on "Towards an Integrated Global Geodetic Observing System" held at Munich, Germany – October 5 – 9, 1998

Indian Regional Navigational Satellite System (IRNSS)

IRNSS - the Indian Regional Navigational Satellite System is a regional satellite navigation system being developed by the Indian Space Research Organization. The system has the overall goal of giving India independent access to accurate navigation and timing data on a 24x7 basis. The deployed constellation will only cover India and surrounding regions with high-accuracy services available about 1500 Km beyond the Indian

Territory. The three GEO satellites will be stationed at 32.5, 83 and 131.5 degrees while the GSO spacecraft will be in two different orbits inclined 29 degrees with longitude crossings at 55 and 111.75 degrees. Each of the two GSO orbital planes contains two satellites spaced 180 degrees in their orbit.

The IRNSS Navigation System will serve a number of applications. It will be used for terrestrial, aerial and marine navigation, precise timing, mapping and geodetic data acquisition, disaster management and vehicle tracking and fleet management. Each IRNSS satellite has a life expectancy of 10 years. Once fully deployed, the IRNSS constellation will provide navigation service to India and surrounding areas as far as 1,500 Kilo meters from the primary service zone that is enclosed by a rectangle of latitude of 30 degrees south to 50 degrees north and longitude of 30 degrees east to 130 degrees east. The Spacecraft will support Standard Positioning Service that is open to all users as well as Restrictive Service with high accuracy that is only provided to authorised users. The system will provide an accuracy of 10 to 20 meters.

For even more precise data, the satellite carries Corner Cube Retro Reflectors that can be used for laser ranging that will yield extremely accurate data. About 6 ILRS stations around India are supporting the launched IRNSS satellites (already three in orbit IRNSS-1A, 1B & 1C) for laser ranging.

Indian Space Research Organization (ISRO) is establishing 2 identical facilities for

1. Satellite Laser Ranging (SLR) – expected operational by 2015
2. Laser Communications (future)

SLR to be performed for POD of India's Navigational (IRNSS) satellites.

Two laser ranging stations are coming up (one at Ponmudi, near Thhiruvananthapuram 8deg.45'N,77deg.E & 600m MSL & and the other at Mt.Abu, Rajastan- 24deg.36'n , 72deg.42É & 1200m MSL) to range the ISROs Navigational satellites (IRNSS)

The purpose of laser ranging to satellites is for:
(i) Preliminary Orbit Determination (POD)
(ii) Ranging to Geodetic satellites for plate tectonic motion and Ocean height variation studies.

The IRNSS satellites are now called NAVIC (Navigationwith Indian Constellation) after Indian PM Declaration on 25th April 2016.

ISRO has launched the following IRNSS satellites carrying laser payload

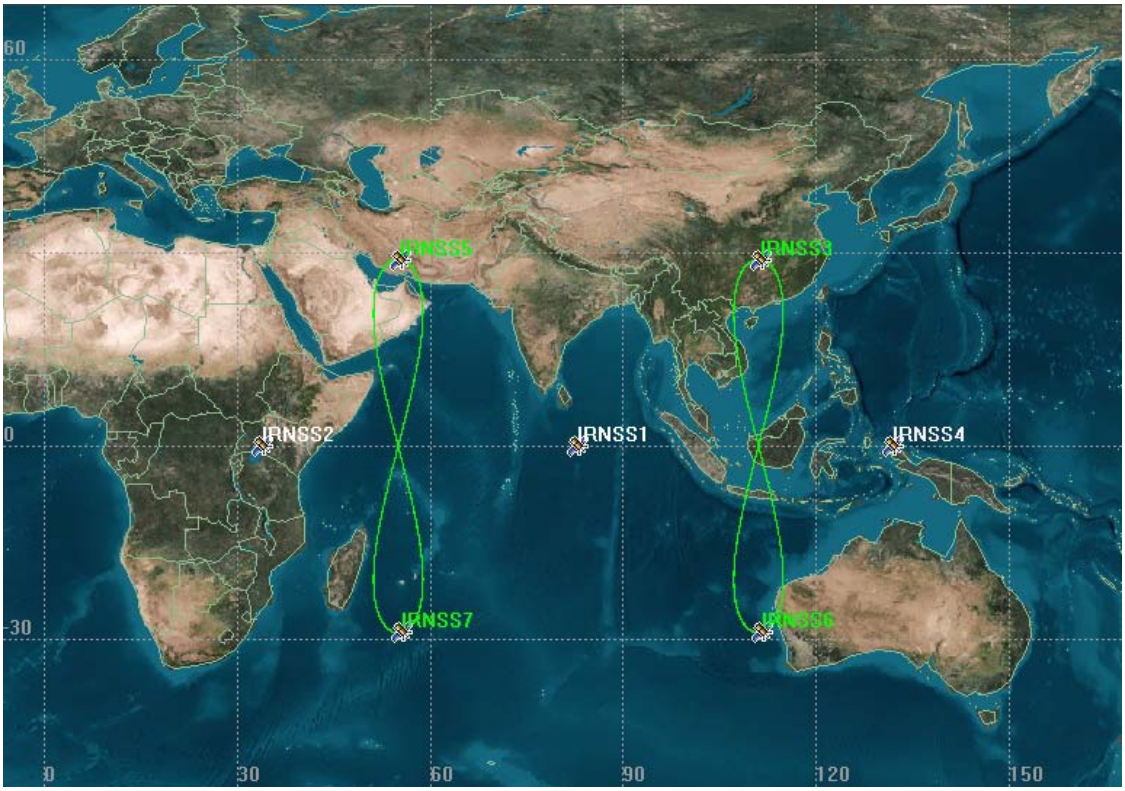
Sl.No.	Launch date	Satellite	Position	Inclination
1	01-07-2013	IRNSS-1A, Geo-Sync.	55 deg.E	29 deg.E
2	04-04-2014	IRNSS-1B, Geo-Sync.	55 deg. E	29 deg.
3	16-10-2014	IRNSS-1C, Geo- Stationary	83 deg. E	
4	28-03-2-15	IRNSS-1D, Geo-Sync.	111.75 deg. E	29 deg.
5	20-01-2016	IRNSS-1E, Geo-Sync.	111.75 deg. E	29 deg.
6	10-03-2016	IRNSS-1F, Geo-Stationary	32.5 deg. E	
7	25-04-2016	IRNSS-1F, Geo-Stationary	131.5 deg. E	

6 – 7 International Laser Ranging Station (ILRS) network is ranging these satellites for POD & OD purposes

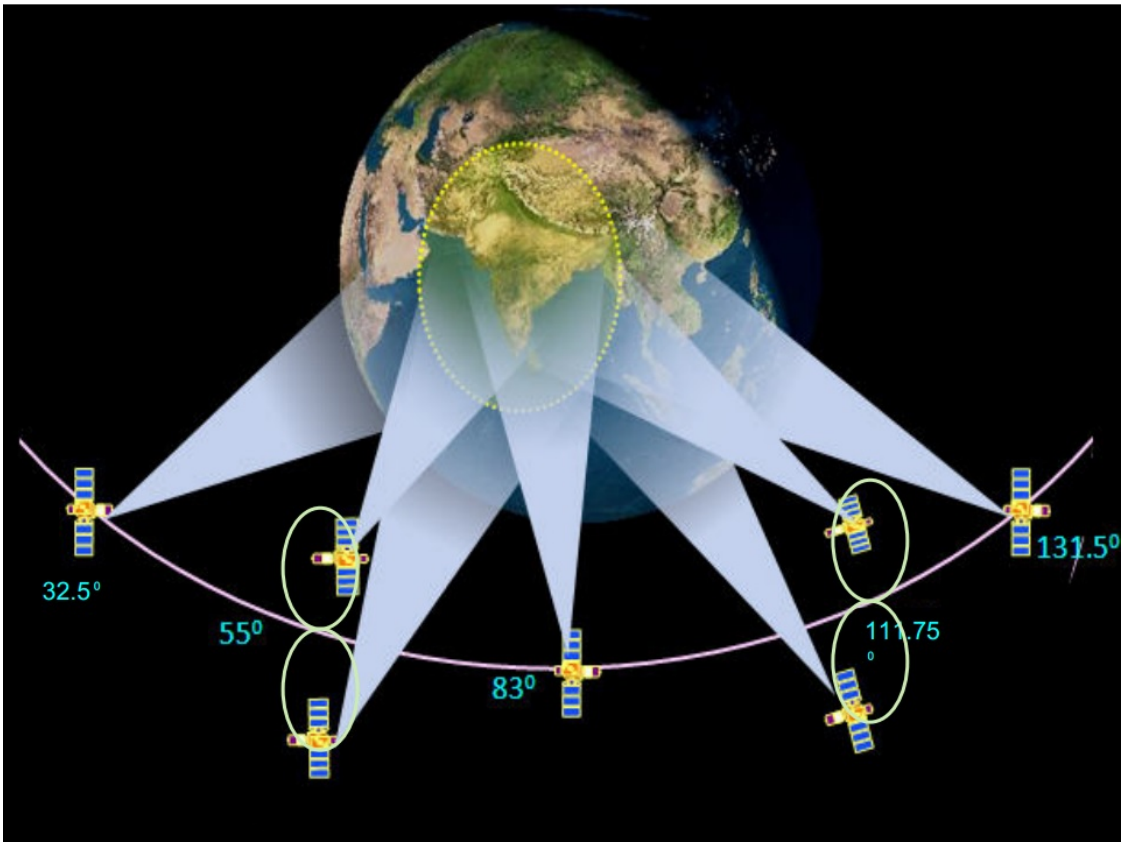
Conclusion

By reviving a laser ranging station at Kavalur, India, will fill the geographic gap in Indian Ocean for geodetic purposes and using this station for future requirements like:

(i) Laser communication
(ii) Lunar Laser ranging
(iii) Joining ILRS network and supporting international satellites
(iv) Dual optics/colour laser ranging
(v) International Space Geodesy Centre



IRNSS Ground Trace



IRNSS Lcations

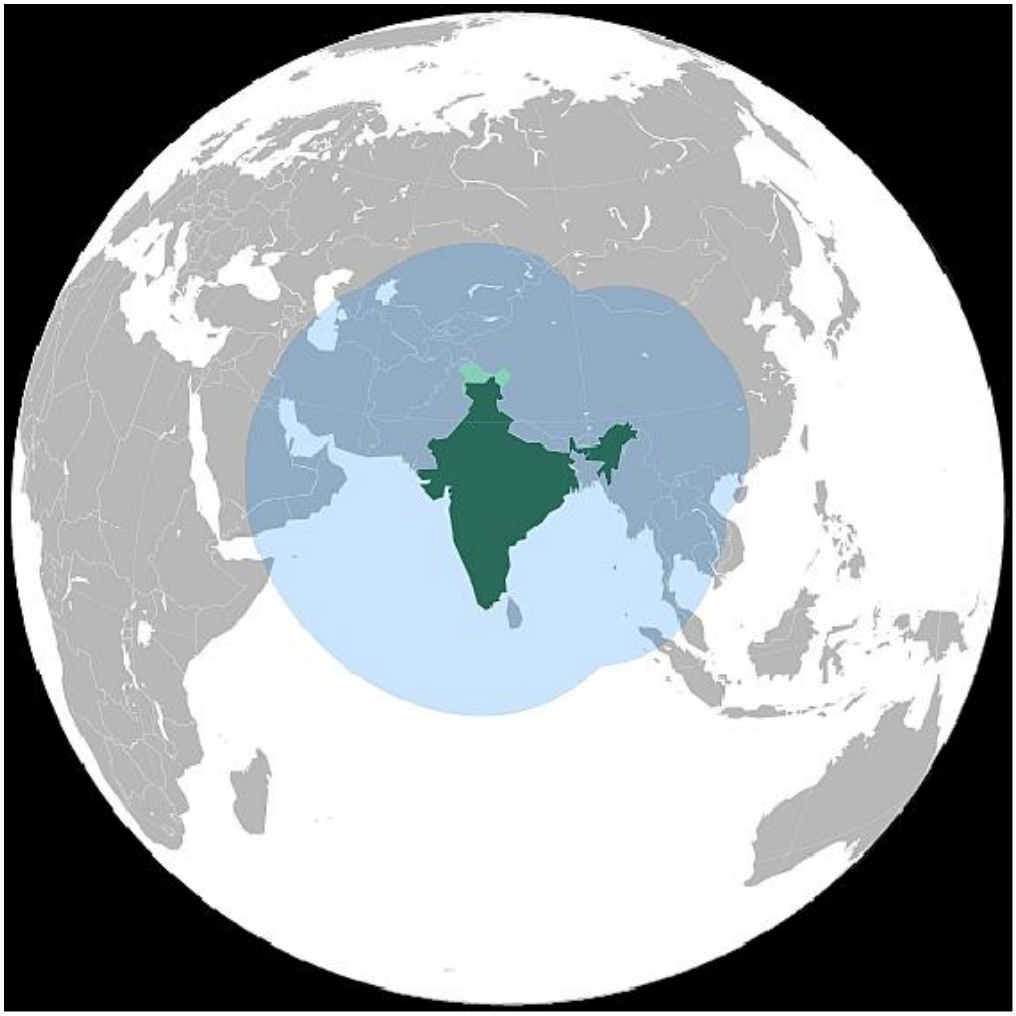
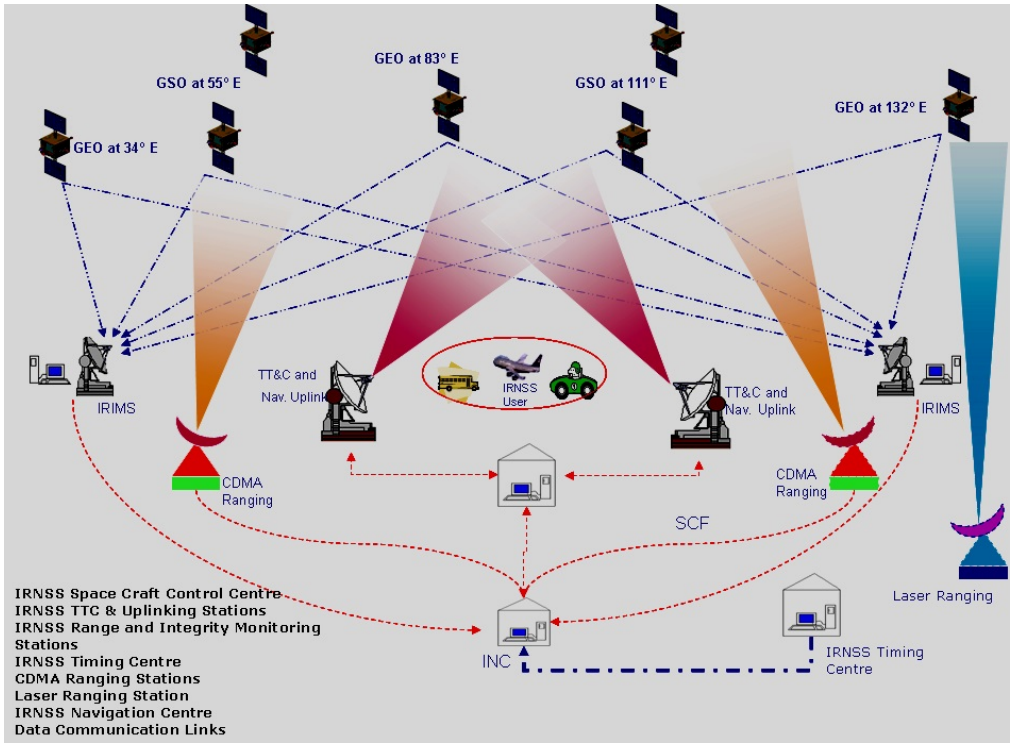


Illustration of the IRNSS coverage which includes an area of ~1500 km around the Indian land mass



IRNSS Control Centre