Deployment of millimeter SLR systems in India with automation features

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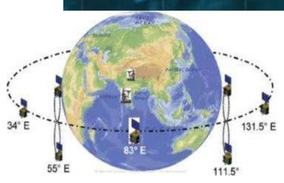
Abstract

Cybioms Corporation is building 2 advanced 1 meter class SLR and photometry systems, for Indian Space Research Organization (ISRO) in support of the already launched IRNSS satellites. These systems are slated for commissioning during Q4, 2016 through Q2, 2017. The systems will also have the capability to incorporate Laser Communications in the future. Advanced servo-control capability for managing the various functions are incorporated. The imaging capability on the Nasmyth side will include adaptive optics for supporting faint objects of magnitude 21 or higher with custom cameras. SLR capability will include provisions for day or night GEO ranging on IRNSS satellites along with the ILRS SLR targets from LEO to HEO satellites. SLR data will generate consistent submillimeter npt precision and accuracy on targets with low target depth function uncertainty. An encircling radar beam along with an ADS-B and a camera will protect the airspace for SLR operations at each station. Some of the automation capabilities support routine operations, reduced human involvement, improved data collections, and monitor / control the two stations from a remote master control facility. Salient points are addressed.

IRNSS Constellation: Regional Navigational Coverage



1. IRNSS Satellites have been launched and are functional in the designated GEO slots;
2. ILRS stations have provided SLR data and continues to track

SPR: Geographical Locations

SPR Site, Mount Abu, <between Jodhpur (Rajasthan) & Ahmedabad (Gujarat)>

Mission Control Facility, Hassan, Bangalore

SPR Site, Ponmudi, <near Trivandrum, Kerala>

Satellite Photometry & Ranging: Primary Mission

1. Primary Mission is to perform Laser Ranging to 7 IRNSS Satellites with retro-reflectors for POD
   - 3 Spacecraft in Geostationary Orbit (33.5E, 83E, 131.5E)
   - 2 Spacecraft in Geosynchronous Orbit (inclination 29°, 55 E)
   - 2 Spacecraft in Geosynchronous Orbit (inclination 29°, 111.5 E)
2. Ranging to Geodetic satellites for tectonic plate motion, ocean height variation studies, etc.
3. **Satellite Photometry & Ranging (SPR) is US Govt. ITAR controlled;**

SPR - Requirements

ISRO needs 2 identical automated facilities for
<1> Satellite Photometry (and Debris Tracking)
<2> Satellite Laser Ranging (SLR) – POD of IRNSS satellites
<3> Laser Communications (future…);
<4> Time transfer

Relies on Advanced Telescopes supporting:

1. **Pointing Accuracy**: <1 arcsec
2. **Resolution**: <0.001 arcsec;
3. **Tracking Jitter** : <0.01 arcsec RMS
4. **Adaptive Optics for atmospheric compensation**
5. **High end imaging capability & Detection Capability**: ~ Magnitude 21
6. **Operations Capability**: Remote Control and Automation for Operations

Satellite Photometry - Major Modules

1. 1 meter Ritchey Chretien Telescope with (1) Coude and (2) Nasmyth Foci
2. 6 meter dome to protect the Telescope /instrumentation from the elements
3. 4kx4k CCD camera for very high sensitivity faint object imaging of magnitude 21 and up
4. Tip-Tilt -Refocus Hardware + Control Software; High frame rate CCD camera for fast imaging and atmospheric compensation
5. Multi-sensor weather station (P, T, H, wind, precipitation, visibility, cloud cover, lightning)
6. State of the art Servo-system for ATP and axes control;
7. Computer HW for device control, data acquisition, data processing, and automation
8. SW to support device control, data acquisition, data processing, and automation

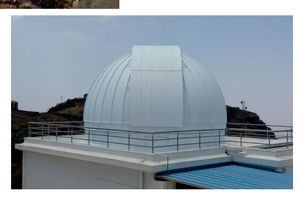
Satellite Laser Ranging – Expected Performance

1. **Full Rate (FRD) Single Shot Precision:**
   - LEO satellites: **< 4mm;** array dependent
   - Lageos: **< 5mm**
   - HEO: **<10 mm;** array dependent
   - GEO: array dependent
2. **Normal Point (NPT) Precision:**
   - LEO satellites: **<1mm**
   - Lageos: **<1mm**
   - HEO: **<1 mm**
   - GEO: **TBD**

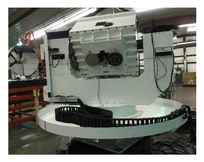
3. Automated application start based on system, external, and target availability, and schedule
4. Automated Tracking based on priorities;
5. Automated Data Processing and Data Transmission;
6. Remote Control and Operations of 2 stations from a Control Cnter;

SPR Implementation – Facility and Domes

1. **Facility** construction completed for both sites; buildings have provisions for future expanded scope of the observatory;
2. 6 meter Dome installation completed at both sites;
3. **Initial Survey** by National Geodetic Survey, India completed at the first site; waiting for the report;
4. Currently in the process of ensuring the adequacy of ALL facilities related matters; remote locations have unique challenges;

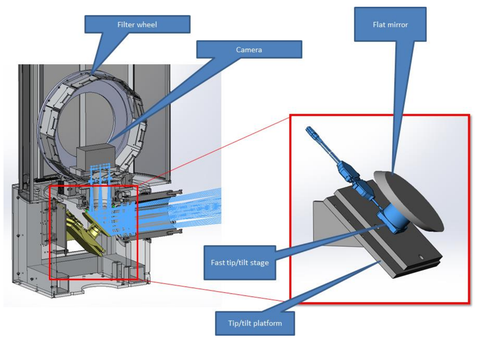


SPR Telescope1: Undergoing testing



Adaptive Optics - Tip-Tilt-Refocus

System will have provision for Tip-Tilt adjustments



Satellite Laser Ranging - Major Modules

1. DPSS Laser Oscillator + FL pumped amp: (20mJ, <30 ps, 50Hz) ; kHz in the near future
2. Time and Frequency electronics
3. TX-RX Electronics: MCP-PMT, APD, Photodiodes, amplifiers, Signal Processing & ET
4. Ranging Control: capable of laser firing, gating devices, collision avoidance,
5. CCD Camera: Target (stars, satellite, etc.) acquisition, and fine telescope pointing
6. Servo-control: Total of 26 axes of servo-control for photometry and SLR;
7. Computing HW for (1) Device control, (2) data acquisition, and (3) data processing
8. SW for (1) Device Control, (2) Data acquisition, (3) Data processing, (4) Automation

SLR: Laser Transmission Safety

1. Tiered Safety Architecture:

- Camera
- ADS-B
- Radar

2. Radar Safety

- X-band radar;
- Automatic capture and monitoring of Radar TX and RX Power levels;
- Automatic capture of AZ, EL, Range, Target Cross-section, dwell time, when detection occurs;
- Discrimination of ground clutter and random noise;
- Will maintain a DB for instances of aircraft intercept data;

SPR: Remote Control and Automation

- World of planetary missions, auto pilot, google and Tesla cars, and others;
- As a general rule, all routine human operational functions can be automated to a high level of precision and repeatability using a combination of HW and SW;
- Tiered approach to achieving high level automation;
- Rule based and learning based approaches; for a multifunctional system, automation is more complex;
- Testing automation takes a lot of time; repeating a process many times adds statistical robustness to observations and a high level of confidence; → $$
- Maintaining a history of system behavior and recognizing the behavioral pattern is fundamental to realizing automation;
- Handling of anomalies and exceptions and getting to the 99% + level …….

SPR : Implementation Schedule

1. Primary facility build up completed;
2. Establishing all ancillary needs of the site;
3. First Telescope to be shipped in ~2 weeks;
4. SLR system to be shipped within 2 months;
5. Radar system within 3 months;
6. SLR Integration expected to be completed by the end of 2016/ early 2017;
7. Second system to follow with a 3-6 month gap;