

ILRS: Current Status and Future Challenges

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- Laser ranging activities are organized under the International Laser Ranging Service (ILRS) which provides global satellite and lunar laser ranging data and their derived data products to support research in geodesy, geophysics, Lunar science, and fundamental constants. This includes data products that are fundamental to the [International Terrestrial Reference Frame \(ITRF\)](#), which is established and maintained by the [International Earth Rotation and Reference Systems Service \(IERS\)](#).
- The ILRS is one of the space geodetic services of the [International Association of Geodesy \(IAG\)](#) and is a member of the IAG's Global Geodetic Observing System (GGOS). The Services, under the umbrella of GGOS, provide the geodetic infrastructure necessary for monitoring global change in the Earth system ([Beutler and Rummel, 2012](#)).

- Organized by the Helmholtz Center Potsdam of the GFZ German Research Centre for Geosciences in Potsdam, Germany during the week of October 09–14, 2016
- Over 170 attendees from 25 countries
- Workshop theme: "The Path Toward the Next Generation Laser Ranging Network"
- 88 presentations, including daily invited talks and over 50 posters: SLR, LLR, intercontinental time transfer; ranging and time transfer through the solar system via the use of asynchronous laser transponders, tracking space debris
- Station clinics on current operational issues
- Proceedings website now collecting all presentations, posters, and papers: <https://cddis.nasa.gov/lw20/Program/index.html>

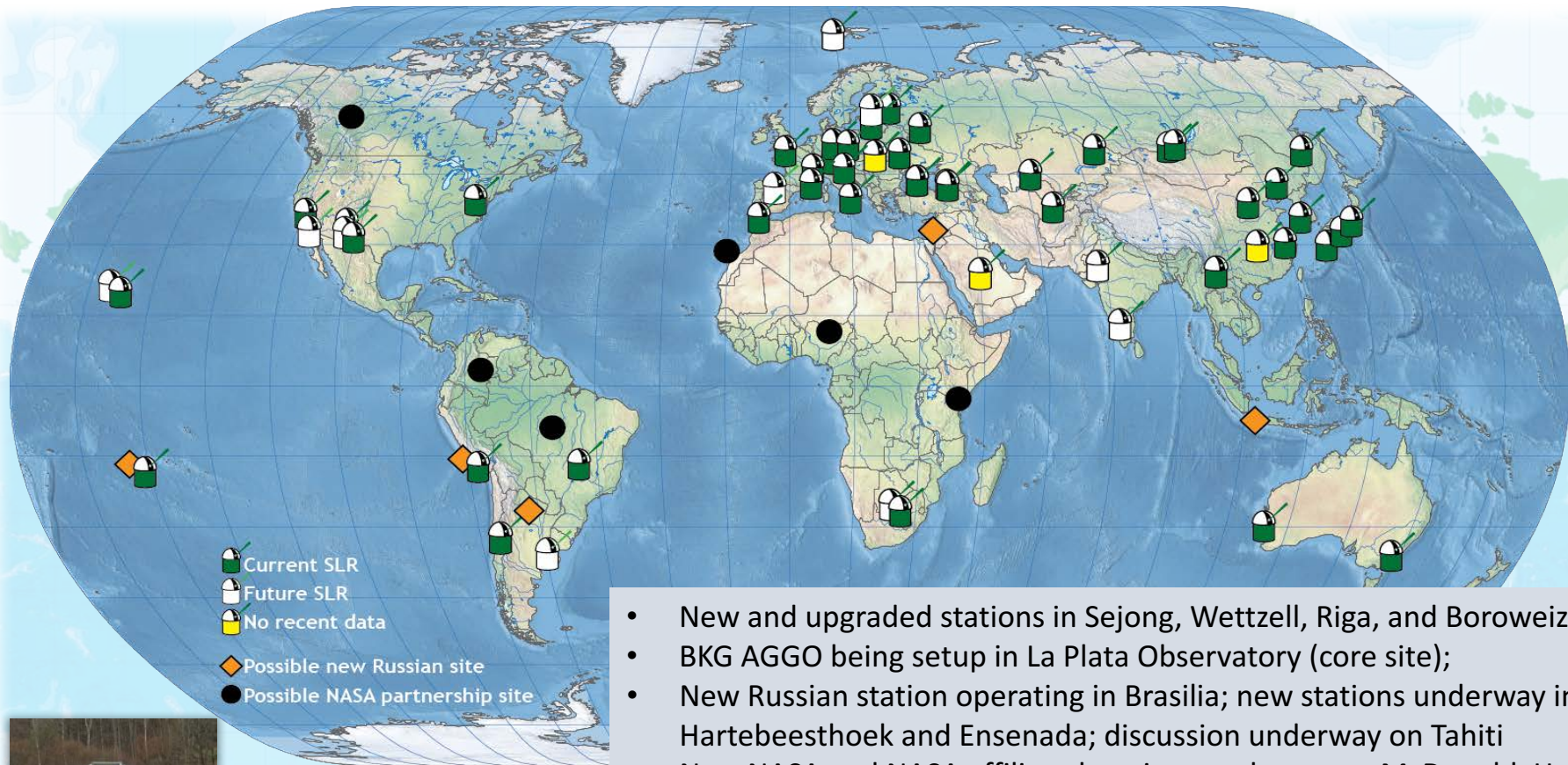


Current trends in SLR



- Lower energy, higher repetition rates (KHz)
- Single photon sensitive detectors (Geodetic Satellite)
 - Single Photon Avalanche Diodes
 - Micro-channel Plate Photomultiplier Tubes
 - Other devices (silicon photomultipliers, nanowires etc.)
- Other wavelengths (near infrared, blue, etc)
- Shorter normal point intervals (take data more quickly) and faster slewing for increased pass interleaving;
- Real-time data evaluation for real-time decision making;
- Automated to autonomous operation with remote access;
- Some stations will have 2 SLR systems to help address the workload;
- Environmental monitoring and awareness for instrument integrity and safety
- Real-time network communication and information sharing;
- Embedded software for real-time updates and decision making;

ILRS network: current and planned



- Current SLR
- Future SLR
- No recent data
- Possible new Russian site
- Possible NASA partnership site

- New and upgraded stations in Sejong, Wettzell, Riga, and Boroweiz
- BKG AGGO being setup in La Plata Observatory (core site);
- New Russian station operating in Brasilia; new stations underway in Hartebeesthoek and Ensenada; discussion underway on Tahiti
- New NASA and NASA affiliated stations underway at McDonald, Hawaii and Ny Alesund NMA),
- New stations underway in Metsahovi, India (2), and Yebes;
- Some discussions with KACST on resurrection of SALRO
- Upgrades underway in Chinese network: San Juan (Argentina), Wuhan, Shanghai



ISRO Satellite Laser Ranging Sites in India

Tom Varghese/Cymbioms Corp



- Facility construction completed for both sites
- Instruments in process; testing underway
- Operation – first half of 2017 and second half of 2017



SPR Site, Mount Abu,

Mission Control Facility, Hassan, Bangalore

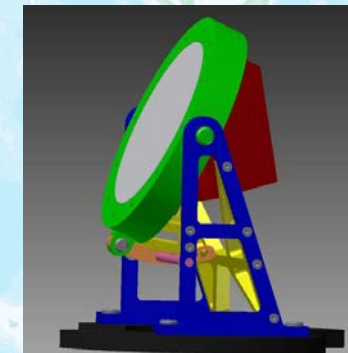
SPR Site, Ponmudi,

See details – Poster by Varghese at:
<https://cddis.nasa.gov/lw20/>



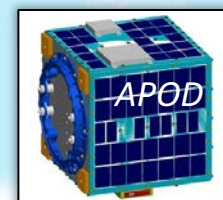
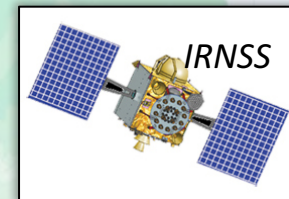
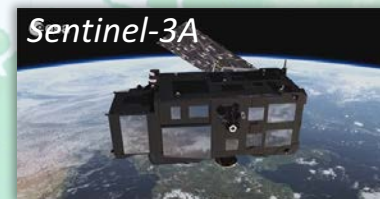
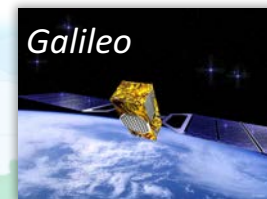
Retroreflector array developments

- Arrays for GNSS satellites
 - Improved station quality may allow lower quality, less expensive corner cubes to be used
 - Investigation of specialized designs for increase cross-section
- Arrays for LEO satellites
 - Work shows “pyramid” type arrays (e.g., Lomonosov) can be are lightweight, inexpensive, and have the required accuracy (0.5 mm)
- Geodetic satellites
 - New array designs for LEO spherical satellites to reduce cost and improve performance
 - BLITS-M type satellites have minimal target error;
- Large Cornercubes (Lunar Ranging)
- Hollow cubes



Mission developments

- List of satellites on ILRS tracking roster continues to grow
 - Routinely tracked over 90 satellites in 2016 (too many)
- In last year, new satellites included:
 - Jason-3
 - Galileo-211 and -212
 - GREAT campaign (Galileo-201)
 - Sentinel-3A (restricted)
 - Lomonosov (restricted)
 - IRNSS-1E and -1F
 - Compass-I6B
 - STPSat-2 second tracking campaign
- Future missions:
 - Additional Beidou/Compass, Galileo, etc.
 - PN constellation (China)
 - Sentinel-3B
 - HY-2C, SWOT, NISAR, COSMIC-2, and IceSAT-2
- Historical Note: LAGEOS 40 year anniversary celebration



- Operational TRF Products: Weekly Station Positions & Daily EOP
- Weekly combination of orbital files (SP3c format) for LAGEOS/ETALON 1 & 2
- Station Systematic Error Monitoring Pilot Project underway (to be complete by mid-2017)
- Next Pilot Project:
 - To deliver low-degree gravity coefficients as a weekly product; and
 - To introduce LARES as the 5th target for TRF products support
- Implementation of ITRF2014 (early 2017) & SLR data reanalysis: 1983 to present
- Journal of Geodesy Special Issue: new call for papers (deadline Jan. 31, 2017)



LRO-LR Measurements

Jan McGarry/NASA GSFC



NGSLR-MOBLAS-7 simultaneous ranging to LRO

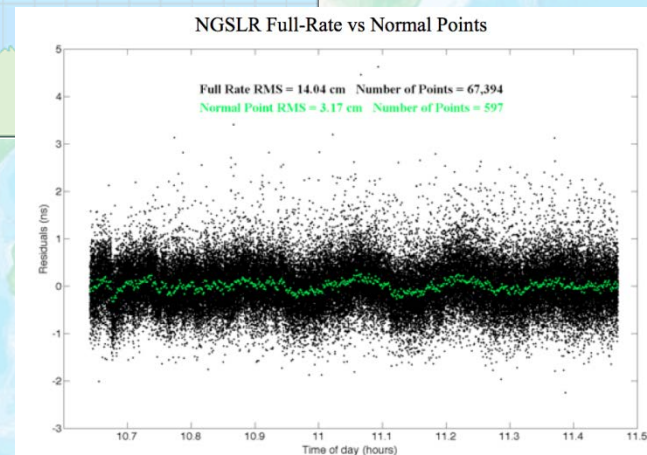


10 participating stations



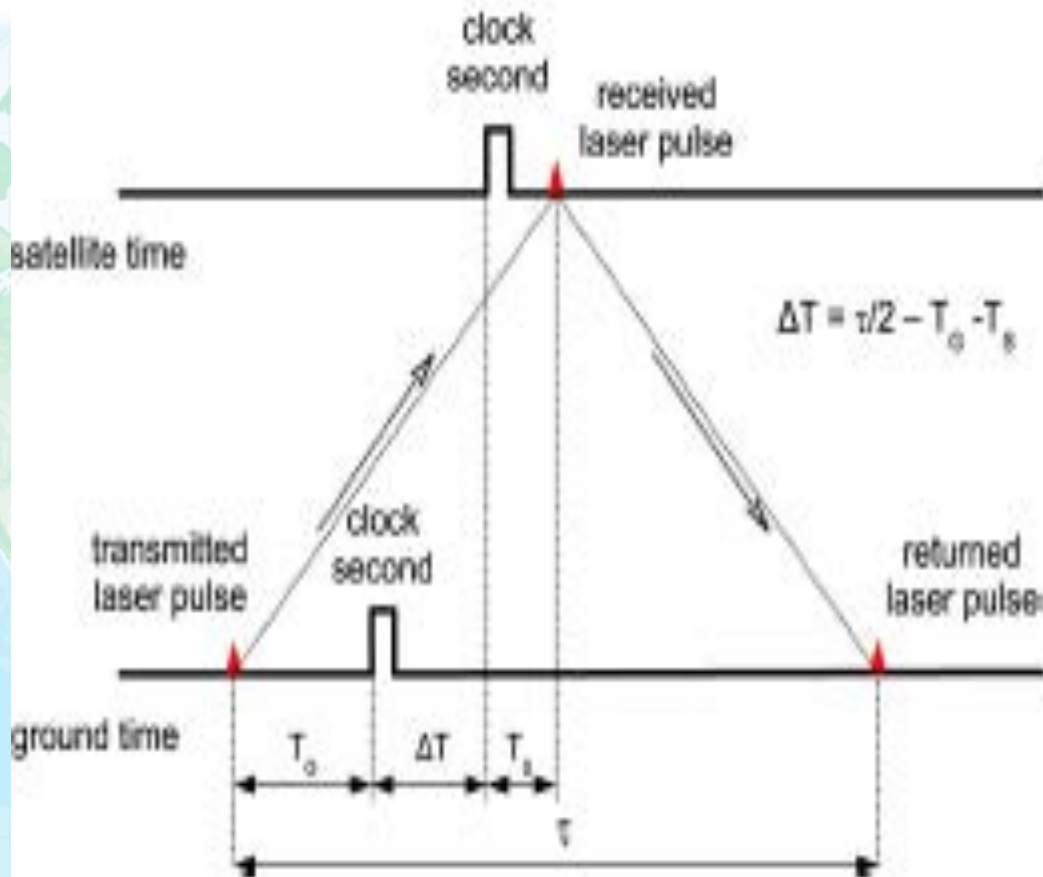
NGSLR to LRO ranging precision: ~ 1 ns (15 cm) stdev

- One-way laser ranging to LRO from 10 ILRS stations : 6/30/2009 to 9/30/2014.
- Enabled a new range measurement capability using existing SLR infrastructures, complementing and potentially replacing RF tracking in the future.
- Demonstrated operational laser ranging to a target orbiting a body other than Earth over a 5 year period.
- Showed that the ILRS Network can be coordinated to provide close to 24 hour coverage for laser ranging to targets beyond the Earth's orbit.



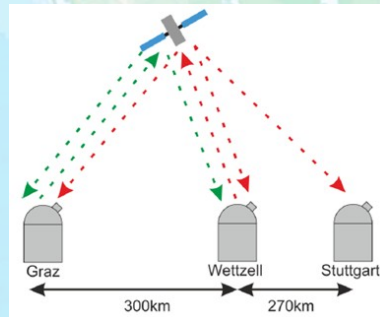
Laser Time Transfer

John Degnan and Ulli Schreiber

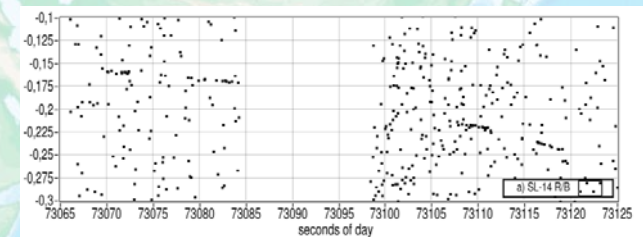


The pulse time of arrival at the satellite coincides with the midpoint of the recorded ground start and stop times which allows one to compute the offset ΔT between the two clocks. If a second ground station performs the same experiment to the satellite, the time offset between the two ground clocks can be determined. Global laser time transfer experiments include L2T2 (France), Compass (China), ELT/ACES (ESA), SOTA (Japan).

- Two-color and multistatic space debris laser tracking¹⁻⁴
 - Graz sends and receives own 532 nm photons, receives Wettzell 1064 nm photons
 - Wettzell sends and receives own 1064 nm photons, receives Graz 532 nm photons
 - Stuttgart receives Wettzell 1064 nm photons
 - Campaign 1: 32 objects, 54 passes; Campaign 2: 35 objects, 162 passes



Stare & Chase: SL14-R/B (NORAD 33505)



- Stare and Chase¹
 - Analog CCD camera + COTS photo objective, piggyback mounted, 50 fps, FoV 7x5°
 - Space debris targets without a priori orbital information pass through field of view
 - Pointing to target detected (equatorial coordinates) --> CPFs calculated
 - Within the same pass: Space debris ranging with new CPFs

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- Many geographic gaps, primarily in Latin America, Africa, and Oceania;
- Mix of new and old technologies and levels of financial support;
- Lack of standardization in system hardware and operations;
- Data quality issues (efforts underway to detect and reduce system biases);
 - New data Quality Control Board established to address laser ranging data quality issues; evaluation and diagnosis of systematic errors; Analysis QC tools, Station diagnostic tools, Communication between stations, OCs, and ACs including forum;
- Number of target satellites continues to increase as new missions use SLR for orbit determination and other applications (90+ satellites);
 - Need to implement more effective tracking strategies
 - Need to be more selective on the targets

