The International Laser Ranging Service and its Support for GGOS

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ABSTRACT

The International Laser Ranging Service (ILRS) was established in September 1998 as a service within the IAG to support programs in geodetic, geophysical, and lunar research activities and to provide data products to the International Earth Rotation and Reference Systems Service (IERS) in support of its prime objectives. The ILRS develops the standards and specifications necessary for product consistency and the priorities and tracking strategies required to maximize network efficiency. This network consists of more than forty SLR stations, routinely tracking nearly thirty retroreflector-equipped satellites and the Moon in support of user needs. The Service collects, merges, analyzes, archives and distributes satellite and lunar laser ranging data to satisfy a variety of scientific, engineering, and operational needs and encourages the application of new technologies to enhance the quality, quantity, and cost effectiveness of its data products. The ILRS works with the global network to improve station performance, new satellite missions in the design and building of retroreflector targets to maximize data quality and quantity, and science programs to optimize scientific data yield. The ILRS Central Bureau maintains a comprehensive web site (http://ilrs.gsfc.nasa.gov) as the primary vehicle for the distribution of information within the ILRS community.

During the last few years, the ILRS has addressed very important challenges: (1) Data from the network stations are now submitted hourly and made available immediately through the data centers, (2) Tracking on low orbit satellites has been significantly improved through the sub-daily issue of predictions, drag functions, and the real-time exchange of time biases, (3) Analysis products are now submitted in SINEX format for compatibility with the other space geodesy techniques, (4) The Analysis Working Group is now generating an operational station position and EOP product, and (5) SLR has significantly increased its participation in the International Terrestrial Reference Frame (ITRF) activity.

ROLE OF LASER RANGING WITHIN GGOS

Global Geodetic Observing System (GGOS) was established by the IAG in 2004 to:

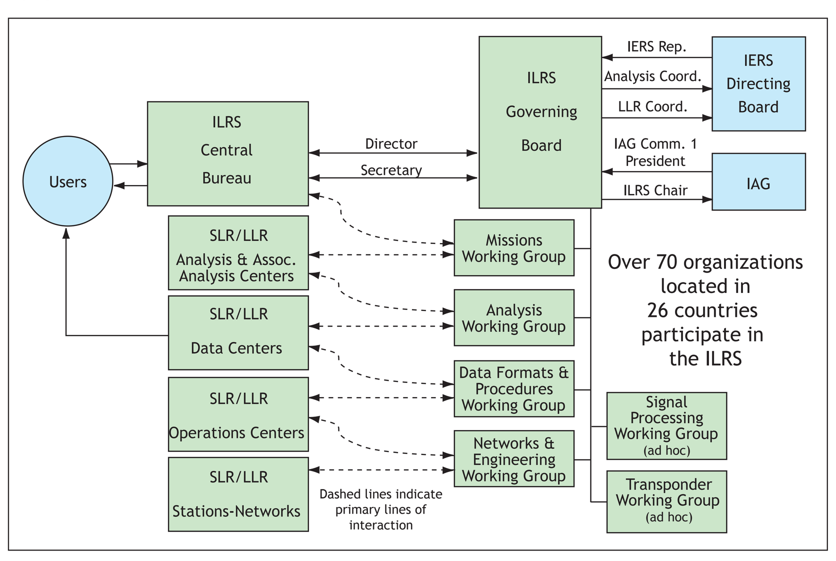
- coordinate geodetic research in support of scientific and applications disciplines;
- integrate different geodetic techniques, models and approaches to provide better consistency, long-term reliability, and understanding of geodetic, geodynamic, and global change processes;
- ensure the robustness of the three aspects of geodesy: geometry and kinematics, Earth orientation and rotation, and static and time-varying gravity field.
- establish a global network of stations with collocated techniques (GPS, SLR, VLBI, DORIS, and gravity field) to support the maintenance and evolution of the global reference system.

Laser Ranging is one of the fundamental techniques in GGOS, providing:

- Earth center-of-mass and scale for the International Global Terrestrial Reference Frame (ITRF) which is the basis through which we connect and compare measurements over space, time, and evolving technologies;
- weekly submissions of polar motion and length of day as an ILRS official product;
- low degree terms of the Earth's gravity field and their secular changes;
- precision orbit determination (POD) and calibration/verification of POD from other techniques (e.g. GPS, DORIS) in support of altimetry for ice, ocean, and land topography mapping;
- Lunar ranging derived products including lunar ephemerides and rotation, dissipation caused deceleration, lunar tidal information, fundamental constants, and geodetic precession.

SLR also provides emergency backup for active tracking techniques having already saved and/or extended the operating lifetimes of ERS-1, GFO-1, TOPEX/Poseidon, and Meteor-3M after the failure of the primary tracking system.

ILRS ORGANIZATION



The International Laser Ranging Service (ILRS) is organized into the following components:

- Tracking Stations and Subnetworks — range to the approved constellation of artificial satellites and the moon
- Operations Centers — collect, QC, merge data from tracking sites and transmit to data centers
- Data Centers — archive laser ranging data and products
- Analysis and Associate Analysis Centers — produce official ILRS products (station coordinates and EOP) as well as special products
- Working Groups — provide expertise to make technical decisions and plan programmatic courses of action
- Central Bureau — coordination and management of ILRS activities
- Governing Board — responsible for general direction of service and defines official ILRS policy

DATA PRODUCTS

Official ILRS Combination Product (Station Position and EOP):

- Five ILRS analysis centers (ASI/Italy, DGFI/Germany, GFZ/Germany, JCET/USA, NSGF/UK) produce weekly solutions on LAGEOS-1 and -2 for global station coordinates and EOP.
- These solutions merged into an Official ILRS Combination Product by ASI (official ILRS Combination Center) and DGFI (backup ILRS Combination Center).
- The Combination Product is furnished to the IERS on a weekly basis for its multi-technique Combination Pilot Project and its Bulletin A.

Scatter of Helmert parameters w.r.t. ITRF2000 of successive weekly ILRS solutions for 2004 (geocenter in mm, scale in ppb)

		Tx	Ty	Tz	Scale
Individual	ASI	3.6	2.5	6.0	0.3
	DGFI	3.8	3.2	7.9	0.5
	GFZ	3.6	5.0	7.3	0.4
	JCET	3.4	3.2	6.6	0.4
	NSGF	5.1	6.9	11.2	0.6
Combination		2.8	2.6	4.9	0.3

Input to the ITRF

- Multiyear solutions (since 1993) on LAGEOS-1 and -2 have been provided for periodic ITRF solutions through ITRF2005
- Pre-1993 data will be combined in a similar fashion in the near future for input into subsequent ITRF solutions

Pilot Projects

- The ILRS AWG has initiated several pilot projects to define standards and reach consensus on official products. These include:
  - Positioning and EOP Pilot Project that defined and implemented the Official ILRS Combination Product
  - Benchmarking Pilot Project that provides internal quality checks and quality control over analysis process and assesses quality of new candidate contributors to the ILRS combination products
  - Other Pilot Projects are organized to examine candidate ILRS products and analysis techniques. At the moment options for Orbital time series is being considered.

New products

- AWG studying production of other official products
- Satellite ephemerides and geocenter time history

ADVANCES UNDERWAY

KHz ranging with faster event timers and better control systems improves data yield and signal-to-noise conditions

- Graz, Austria first to successfully operate 2 kHz laser system, increasing data volume up to two orders of magnitude
- SLR2000, USA under development
- Other stations in the process of purchasing the hardware.

Increased automation reduces cost and facilitates throughput

- Mount Stromlo, Australia fully automated and operational
- Zimmerwald, Switzerland automated operation several hours/day
- SLR2000, USA fully automated in testing

New, more powerful stations provide a better dynamic mix of ranging capability

- Meter-class telescopes with state-of-the art optical and mechanical performance
- Matera, Italy and Tanegashima, Japan achieve few mm single-shot range precision

Two-color ranging could be a means for development of better models for atmospheric refraction delay

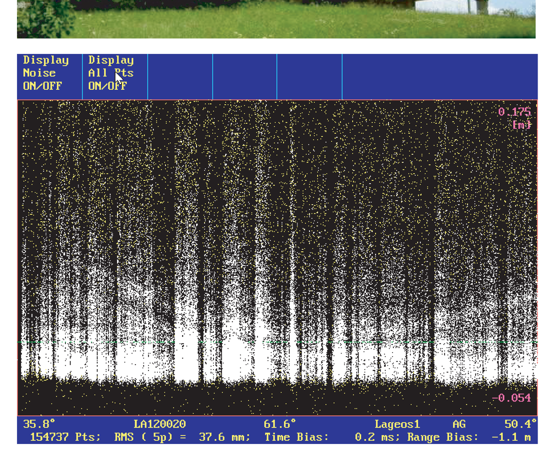
- In operation at Concepción (Argentina) and Zimmerwald (Switzerland)
- Tested at Matera, Italy and GSFC

Improved satellite retroreflector array models and design will improve ranging accuracy

- Parameterize ground station models to help standardize satellite models
- Some recently-launched satellites use standard arrays with restricted cornercube view to minimize multi-cube returns
- Russian satellite with Luneberg sphere under development; will give same array correction for a variety of aspect angles

Optical transponders offer promise of ranging to considerably greater distances

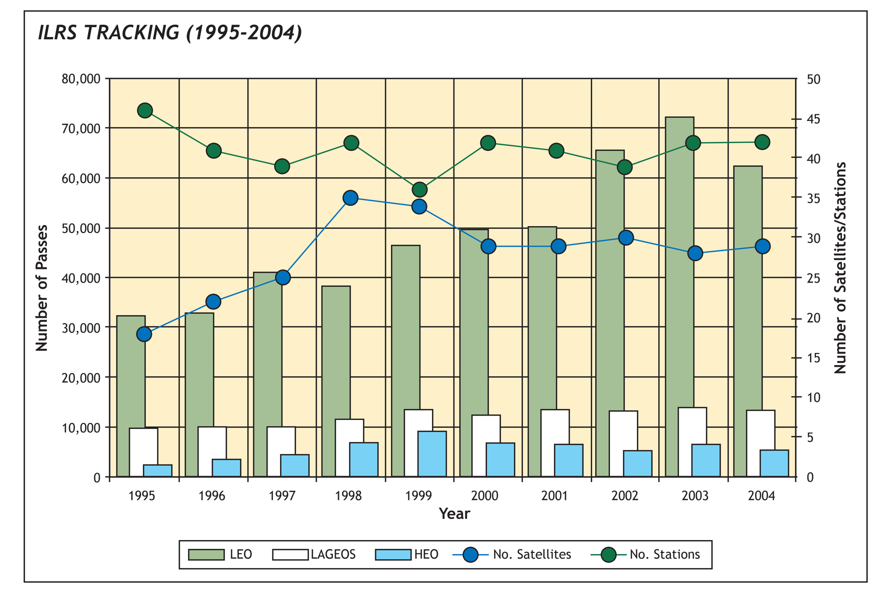
- Combination of laser-ranging receiver and separate laser pulse transmitter
- Optical transponders for extraterrestrial ranging under development
- Offers ranging to Mars, planetary moons, orbiters, and deep space missions
- Would help to connect terrestrial reference frame with reference systems used for planetary missions

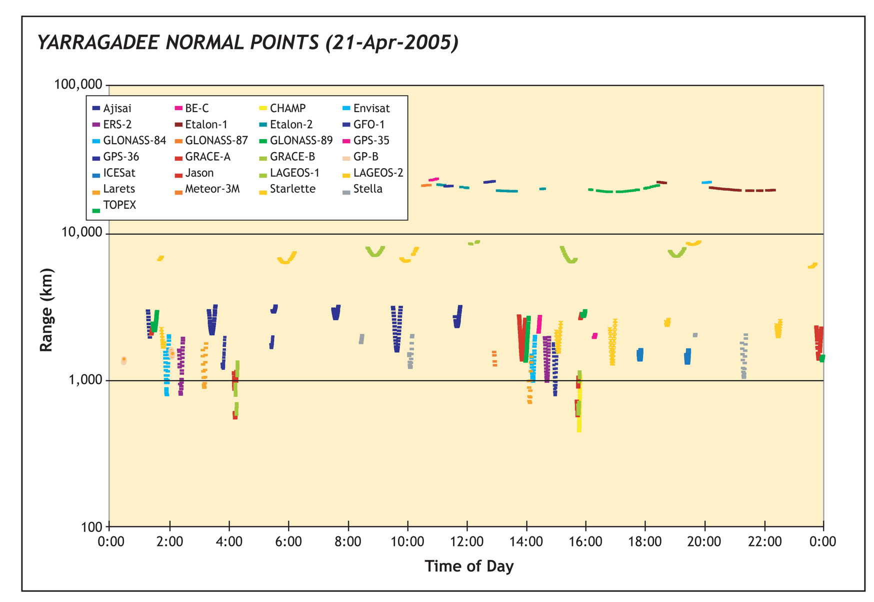


Single retroreflector tracks of LAGEOS-1 as observed with the Graz kHz laser ranging system. The figure indicates that the satellite's rotation has stopped (more or less), allowing, at least in some passes, to see the various groups of retroreflectors. LAGEOS-2 (launched in 1992) does NOT show such signatures, indicating that it is still rotating. (Figure provided by G. Kirchner/Austrian Academy of Sciences)

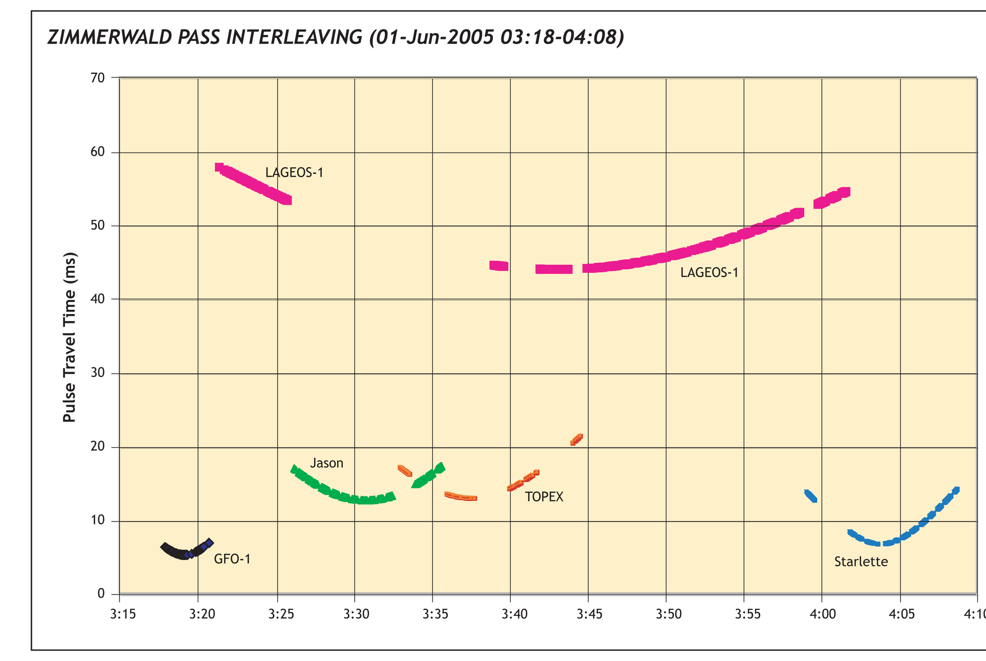
NETWORK PERFORMANCE

- Data yield continued to improve through 2004 as stations implement automated procedures and new satellites are added to the tracking roster.
- In 2004, NASA network suffered severe budget reductions which resulted the closing of some stations and reductions in others, with commensurate decrease in data yield.
- Actions are underway to reopen the closed stations in Maui and Arequipa.

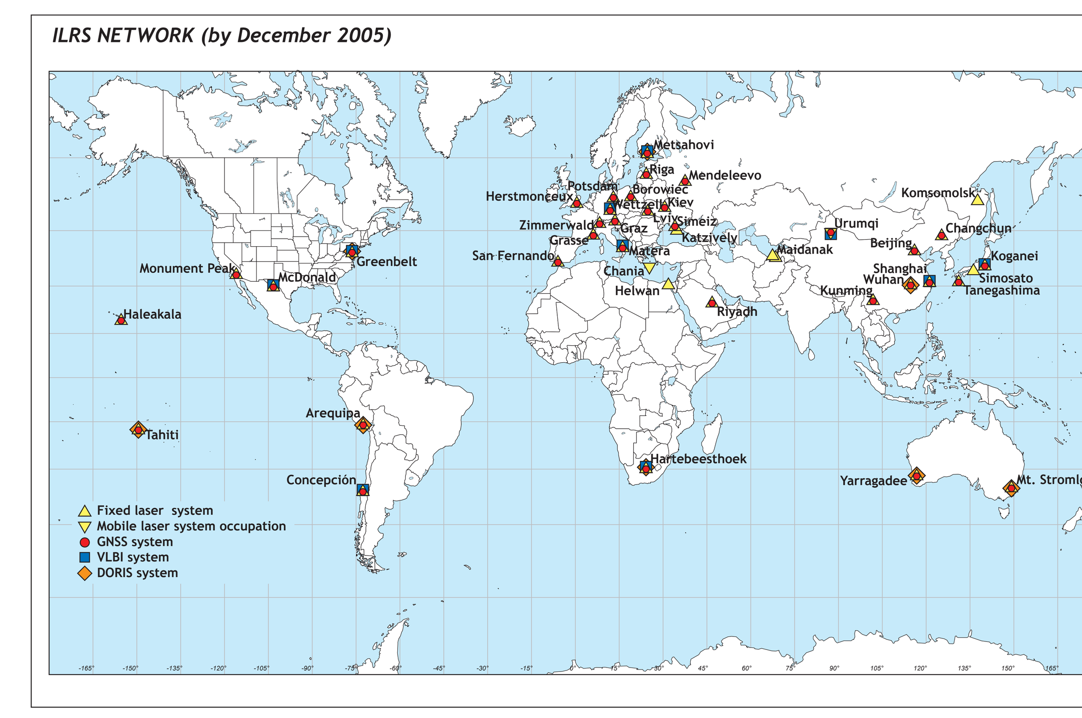




An example of a productive day of laser tracking at Yarragadee, Australia.
Figure courtesy of Vince Noyes and Randall Carman/MOBLAS-5.



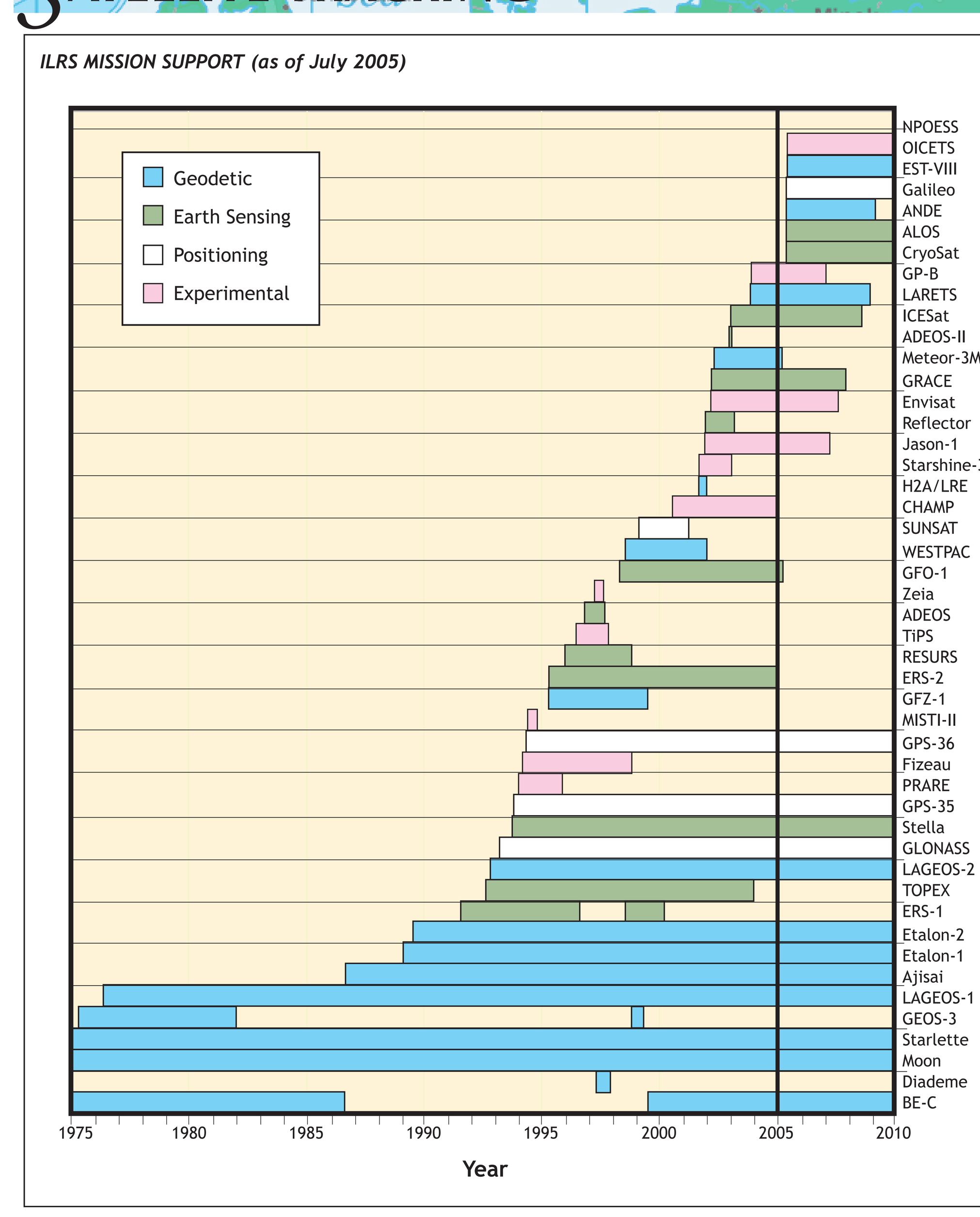
Most of the current laser tracking stations range ten times per second during part or all of the satellite pass, with many stations interleaving passes from different satellites



The ILRS network consists of 40 operational stations in 23 countries (38 fixed, 2 mobile):

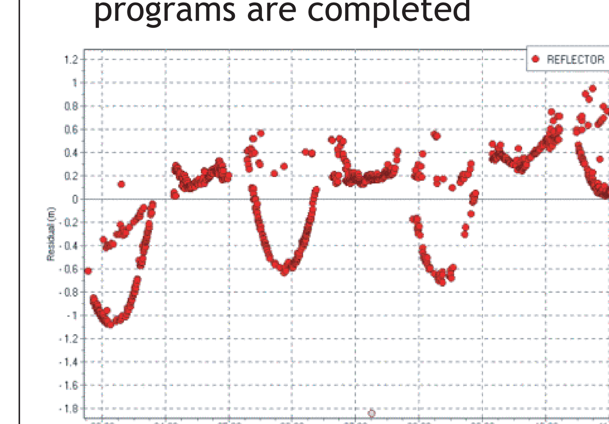
- *35 are co-located with GNSS receivers*
- *10 are co-located with VLBI antennas*
- *8 are co-located with DORIS*

SATELLITE TRACKING

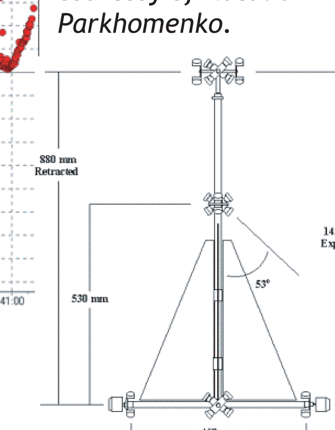


ILRS Satellite Support

- SLR has tracked more than fifty satellites with retroreflectors
- Today, the ILRS tracks 28 satellites for geodynamics, remote sensing (altimeter, SAR, etc.), gravity field determination, general relativity, verification of global navigation systems satellite orbits, and engineering tests
- Satellite altitudes range from a few hundreds of kilometers to GPS altitude (20,000 km)
- A few stations routinely range to four targets on the Moon
- Satellites are added and deleted from the ILRS tracking roster as new programs are approved by the GB and old programs are completed



SLR observations of Reflector by Yarragadee in December 2001. Figure courtesy of Natalia Parkhomenko.



Reflector microsatellite diagram. Figure courtesy of Natalia Parkhomenko.

Future Plans

- New missions scheduled for ILRS tracking support over the next year include CryoSat, ALOS, OICETS, and the first two engineering versions of the Galileo satellites (GSTB-V2A and GSTB-V2B)
- It is anticipated that the full thirty satellite Galileo complex, to be launched between 2007 and 2008, will require, at least intermittent, SLR tracking.

Specialized missions

- The ILRS supports space engineering studies on some rather unique missions
- The Russian Reflector satellite included retroreflectors over its nearly 1 1/2 meter length; differences in the laser return time-of-arrival were used to interpret the orientation and dynamics of the satellite
- The Naval Research Laboratory's Tether Physics and Survivability satellite, (TiPS) with retroreflector arrays on two satellites separated by a four-kilometer tether was tracked by SLR to study tether dynamics in space.

CONCLUSIONS AND ACKNOWLEDGEMENTS

- Laser ranging has proven to be a fundamental component of the space-geodetic complex, offering a straightforward, conceptually simple and highly accurate observable.
- Laser ranging provides essential contributions to geosciences, space sciences and fundamental physics. It will play an important role in the GGOS project.
- Current and future challenges lie in the improvement of the accuracy, reliability and availability of the data and in the long-term support of the network.
- Many of the technological building blocks for the next generation of laser ranging have already been demonstrated.
- Implementation of these technical building blocks will bring dramatic improvements to the capability of the technique.

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FOR FURTHER INFORMATION

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