INTERNATIONAL LASER RANGING SERVICE

1999
ANNUAL REPORT

May 2000

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and L. Taggart

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PREFACE

This 1999 Annual Report of the International Laser Ranging Service (ILRS) is comprised of individual contributions from ILRS components within the international geodetic community.

This report documents the work of the ILRS components from the inception of the Service through December 31, 1999. Since the Service has only recently been established, the ILRS associates decided to publish this Annual Report as a reference to our organization and its components.

All of the content of this Annual Report also appears on the ILRS website at:

http://ilrs.gsfc.nasa.gov/ilrsar_1999.html

This book and the website are organized as follows:

The first section of the Annual Report contains general information about the ILRS, it's mission, structure and Governing Board. Professor Gerhard Beutler's introductory remarks and the ILRS Chairman's report give a brief background and history of the ILRS and an overview of its organization.

- Section 1, the Governing Board Report, provides an overview of the ILRS, a brief history of its origin and establishment, the contributions that it provides to the scientific community, its interface with other organizations and a view on future prospects.
- Section 2, the Central Bureau Report, provides reports on the current status of Central Bureau activities, mission priorities, network campaigns, upcoming missions, the ILRS website, Network performance evaluations and a report from the ILRS Science Coordinator.
- Section 3 includes the Working Group Reports, including accomplishments during the last year, and activities underway, as well as those planned for next year. The Working Groups have originated and developed many standards and procedures that have been implemented by the ILRS.
- Sections 4, 5 and 6 include Network, Operation Center and Data Center Reports. These sections provide the status of the data chain from the point of SLR data acquisition through archiving.
- Section 7 includes the Reports for the SLR Analysis and Associate Analysis Centers, as well as the LLR Analysis Centers. These reports include information on the data products generated by each, their computational capabilities and facilities, their personnel and their future plans.

The last section provides ILRS reference material: the Terms of Reference, a list of institutions contributing to this Annual Report, the list of ILRS Associate Members, a complete list of the ILRS components and a list of Acronyms.

The ILRS 1999 Annual Report will be a valuable reference for information about the ILRS and its components.

ACKNOWLEDGEMENTS

The editor would like to acknowledge the essential contributions of the following people to the preparation of the ILRS 1999 Annual Report:

- Carey Noll and Van Husson assembled many of the charts and figures for the report.
- Linda Taggart helped to edit the text and formatted and assembled the document.
- John Hazen designed the cover art and the layout for the color pages of the report.

Finally I would like to thank all of the ILRS colleagues who provided their contributions to the Annual Report.

Mike Pearlman
Secretary, ILRS Central Bureau

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The ILRS:

A New Approach for the World-Wide Coordination of Laser Tracking of Artificial Satellites and of the Moon

Gerhard Beutler Vice-President of the International
Association of Geodesy (IAG)

When I was asked by Dr. Michael Pearlman to write a preface for the first annual report of the International Laser Ranging Service (ILRS) I was honored, but answered by asking Mike whether he knew that I was no longer President of CSTG and thus had "nothing whatsoever to do with the ILRS service". I thought he might ask me to say few words "on behalf of IAG" as its newly elected Vice-President. Dr. Michael Pearlman replied "oh, you know, you still are the ILRS uncle, and we have your picture pinned at the wall". I thus try to say a few words as an uncle and as Vice-President of IAG. The two roles are, by the way, not mutually exclusive.

Most of my colleagues believe that my background is in GPS. I have to confess, however, that I was heavily involved in Satellite Laser Ranging (SLR) between 1976 and 1983, when we tried to build up what was called at that time the "new" SLR Observatory in Zimmerwald. It is remarkable that the success only came one year after I had left, when my colleague, Prof. Werner Gurtner, took over the position as manager of the Zimmerwald observatory.

I learned several things from my personal engagement in the stimulating environment of SLR: First, I understood, that my professional skills were more in the area "mathematical methods, theory, etc" and less in technology oriented, operational and organizational matters. I was therefore glad to find a new challenge in developing algorithms for processing GPS observations.

Secondly, I learned that in the era of space geodesy Laser ranging is the only calibration method for the other modern space geodetic techniques because in the optical and near infrared domain of the electromagnetic spectrum the signal delays due to the Earth's atmosphere may be taken into account on the level of one centimeter or better, provided pressure, temperature and humidity are continuously monitored at the SLR/LLR tracking sites.

This must be seen in contrast to the VLBI technique and precise satellite microwave systems (GPS, GLONASS, DORIS, etc.) using the microwave part of the spectrum, where tropospheric refraction may be taken into account (using the same surface met data) only on the level of about 10cm. For regional and global applications VLBI, GPS, etc. only achieve accurate results thanks to highly sophisticated troposphere modeling techniques.

The SLR observation on the other hand "only" relies on

- the assumption of the constancy of the speed of light in vacuum (where I am a bit concerned that people only know the least significant three digits "458")
- modern Laser technology producing very short (50-100 picoseconds) light pulses of a very small divergence,
- the assumption that the satellite (artificial or natural) is equipped with one or more retroreflectors sending the light back into the incident direction, and
- extremely accurate time interval counters allowing to measure the light traveling time with picosecond resolution.

The first "assumption" actually is one of the best established laws of nature —- it is the basis for the theory of relativity and it is even used to define the meter via the second in the SI-system. The remaining three assumptions are well taken care of by state of the art technology.

The SLR/LLR observation is easily understood and interpreted: Half of the light traveling time (after subtraction of the atmospheric signal delay) is the geometrical distance between observatory and satellite at reflection time of the signal at the satellite. The single shot observation is unbiased and accurate to about one centimeter. Higher accuracies are achievable through normal point techniques.

Everybody knows that the investments on ground for SLR and/or LLR tracking are substantial. The investments in the space segment are minor, however. This is an important argument to keep SLR tracking alive as an accurate backup orbit determination tool.

Laser Ranging is a comparatively old space geodetic observation technique. We owe it much and deep insight in geodesy and geophysics: Our knowledge of the Earth gravity field is to a great extent due to SLR observations The motion of the moon is known with unprecedented accuracy thanks to LLR, yielding among other, the best test basis for different gravity theories. SLR and VLBI together were the observation techniques of the 1980s leading to the first accurate realization of the global ITRF, the International Terrestrial Reference Frame.

With the advent and the success of the GPS in space geodesy, for scientific applications coordinated by the IGS, the International GPS Service, a heavy pressure was exerted on the SLR/LLR and the VLBI communities: It was argued that the new satellite microwave systems could provide in a much cheaper way the entire spectrum of parameters of geodetic and geophysical interest than the traditional techniques —- of course without mentioning that the SLR-derived gravity field was an absolute prerequisite for success of IGS.

Counterarguments were, as indicated, readily at hand. It was also obvious, however, that the older techniques had to learn from the newly created IGS: Only if SLR/LLR (and the VLBI) products would be made regularly available with short delays after the observation and in a format common to all techniques, the "routine" SLR tracking would be able to contribute significantly to space geodetic time series in future, as well.

Mid of the 1990s the SLR/LLR community started considering the replacement of its CSTG subcommission by an international organization comparable to the IGS. The tenth International Workshop on Laser Ranging Instrumentation in Shanghai, China (November 11-15, 1996) may be viewed as the starting point for the development of the ILRS: An open and general discussion including all participants of the workshop reveiled that the SLR/LLR community was determined to move into the direction of a more product-driven and service-oriented organization. At the Shanghai meeting of the CSTG Subommission SLR/LLR the decision was taken to write Terms of Reference for the new organization. A group led by John Degnan, SLR/LLR subcommission president at that time, started working immediately. The Terms of Reference and a Call for Participation were written in less than six months. Both documents were accepted first by the CSTG Executive committee, then by the IERS, finally by the IAG Executive Committee in 1997. The Call for Participation was sent out on 28 January 1998. The success was overwhelming: The entire SLR and LLR community joined the effort. In fall 1998 the new service started operating.

It is remarkable that the structure of international SLR and LLR cooperation could be revised and put on a completely new basis within only two years. The CSTG Subcommission and the ILRS Governing Board, their President and secretary, Drs. John Degnan and Michael Pearlman, and the entire SLR and LLR community must be congratulated for this achievement. The creation of the International Laser Ranging Service ILRS must be considered as a great success story in space geodesy. It gained a lot of new momentum for this proud space geodetic technique.

The first Annual Report of the ILRS documents that the initial phase of of the ILRS was very satisfactory as well. On behalf of IAG and its Executive Committee I would like to thank the ILRS Governing Board and the entire community for their work.

Let me conclude by wishing the ILRS many fruitful years and informative annual reports. If the ILRS preserves the spirit governing its creation and its initial operational phase I have no doubt that the community is well prepared to meet the challenges of the future, as well. The community knows that the planetary systems is in reach of the Laser Ranging Technique —- one "only" has to replace the laser reflectors by optical transponder systems and the targets by planets ...

CHAIRMAN'S REMARKS

The International Laser Ranging Service (ILRS) was created on 22 September 1998 at the 11th International Workshop on Laser Ranging in Deggendorf, Germany. The Central Bureau (CB) was established at the NASA Goddard Space Flight Center with John Bosworth and Mike Pearlman respectively serving as Director and Secretary. The first ILRS General Assembly coincided with the final meeting of the predecessor CSTG Subcommission on Satellite and Lunar Laser Ranging, which I had the honor of chairing for several years. The newly elected Governing Board was installed, and various members were chosen to serve as Coordinators and Deputy Coordinators for the four standing Working Groups (WG's) - Missions, Data Formats and Procedures, Networks and Engineering, and Analysis. In July 1999, the ILRS was elevated to the rank of an IAG Service by the IAG Directing Board, on an equal footing with the established International GPS Service (IGS) and the newly created International VLBI Service (IVS), with close ties and representation on the International Earth Rotation Service (IERS) Directing Board.

In creating the structure for the new ILRS, the WG's were intended to be the focal points for most Governing Board activities and are now being emulated in the other space geodetic services. The WG's recommend policy or actions in their areas of responsibility which are then voted on by the full Governing Board. They are also responsible for recommending and/or providing additional materials to the CB for inclusion in the knowledge databases. Although the WG concept is a carryover from the old CSTG SLR/LLR Subcommission, it is my perception that the implementation and effectiveness of the WG's has been greatly enhanced in the new organization. This is due to several factors including the leadership of the GB Coordinators and Deputy Coordinators in formulating and carrying out action plans and attracting high caliber researchers to serve on the WG's, some of whom directly support the CB. This close coupling of the Governing Board, the Working Groups, and the Central Bureau has allowed rapid progress to be made during our first 18 months of operation. ILRS Associates who wish to volunteer their time or ideas are encouraged to contact the appropriate WG Coordinator.

In preparing this first Annual Report of the ILRS, we felt that it would be useful to include some fundamental information on the history, organization, and services provided by the ILRS. We hope that you will find it to be a useful reference in the future. Our Secretary, Mike Pearlman, is to be specially commended for his doggedness in bringing it all together.

We also wish to give special thanks to Linda Taggart of Raytheon ITSS for her tremendous effort in working with Mike on the editing and assembly of this document.

Finally, all ILRS Associates and Correspondents are encouraged to visit the ILRS Web Site at http://ilrs.gsfc.nasa.gov where you will see the fruits of our early labors first hand.

John J. Degnan
ILRS Governing Board Chairperson
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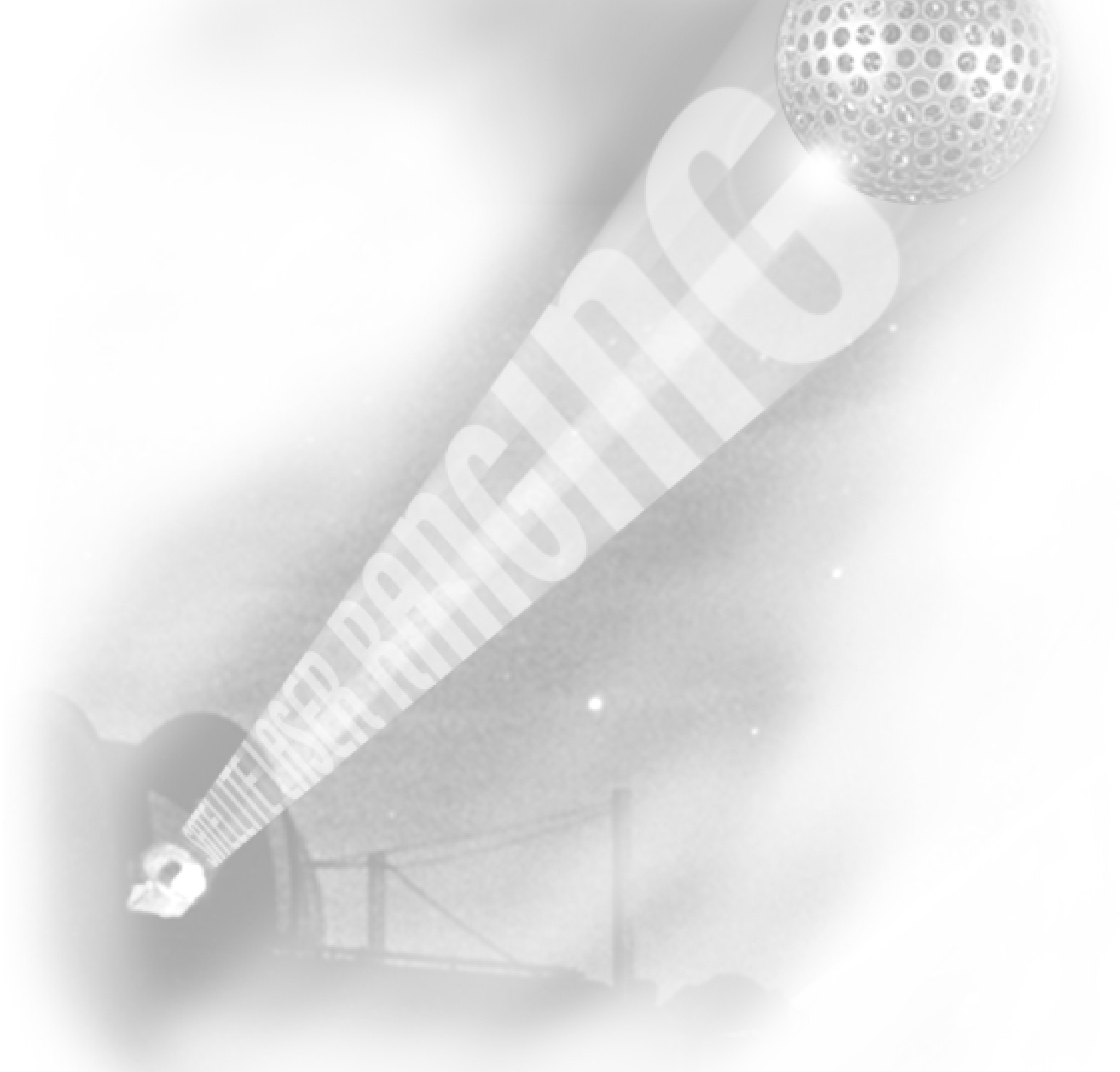
ABOUT ILRS



ILRS Organization

Mission:

The International Laser Ranging Service (ILRS) organizes and coordinates Satellite Laser Ranging (SLR) to support programs in geodetic, geophysical and lunar research activities and provides the International Earth Rotation Service (IERS) with products important to the maintenance of an accurate International Terrestrial Reference Frame (ITRF).

Role:

ILRS is a service of the International Association of Geodesy (IAG), originally established under IAG Commission VIII—the International Coordination of Space Techniques for Geodesy and Geodynamics (CSTG).

ILRS is the second of this type of service to be established. The first was the IGS (International GPS Service) which has been highly successful as a service for GPS.

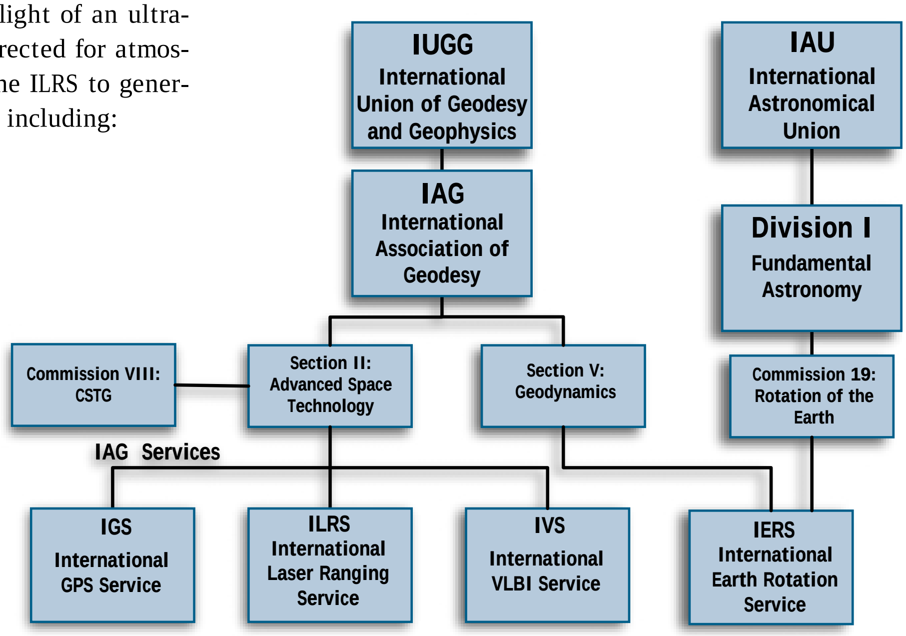
The ILRS develops (1) the standards and specifications necessary for product consistency and (2) the priorities and tracking strategies required to maximize network efficiency. The service collects, merges, analyzes, archives and distributes satellite and lunar ranging data to satisfy a variety of scientific 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 (1) new satellite missions in the design and building of retroreflector targets to maximize data quality and quantity and (2) science programs to optimize scientific data yield.

The basic observable is the precise time-of-flight of an ultrashort laser pulse to and from a satellite, corrected for atmospheric delays. These data sets are used by the ILRS to generate a number of fundamental data products, including:

- Centimeter accuracy satellite ephemerides
- Earth orientation parameters (polar motion and length of day)
- Three-dimensional coordinates and velocities of the ILRS tracking stations
- Time-varying geocenter coordinates
- Static and time-varying coefficients of the Earth's gravity field
- Fundamental physical constants
- Lunar ephemeredes and librations
- Lunar orientation parameters

All ILRS data and products are archived and are publically available.

The organizations listed in Section 8.7 contribute to the ILRS by supporting one or more ILRS components.

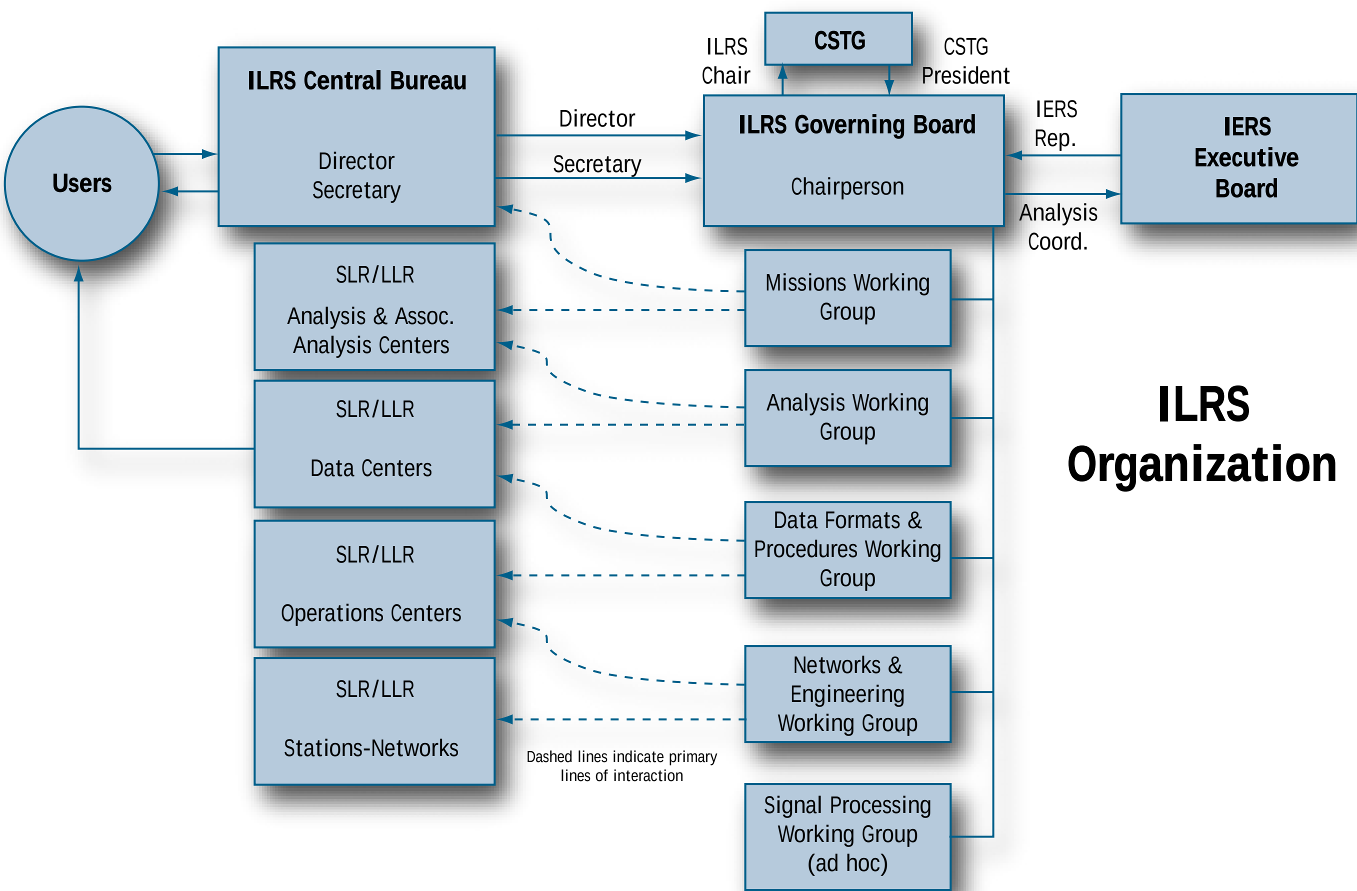


Structure:

The ILRS is organized into permanent components:

- a Governing Board,
- a Central Bureau,
- Tracking Stations and Subnetworks,
- Operations Centers,
- Global and Regional Data Centers and
- Analysis, Lunar Analysis and Associate Analysis Centers.

The Governing Board, with broad representation from the international SLR and LLR community, provides overall guidance and defines service policies, while the Central Bureau oversees and coordinates the daily service activities, maintains scientific and technological databases and facilitates communications. Active Working Groups in (1) Missions, (2) Networks and Engineering, (3) Data Formats and Procedures, (4) Analysis and (5) Signal Processing provide key operational and technical expertise to better exploit current capability and to challenge the ILRS participants to keep pace with evolving user needs. The ILRS currently includes more than 40 SLR stations, routinely tracking about 20 retroreflector-equipped satellites and the Moon in support of user needs.



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ILRS Component Map


FFI
Metsahovi
IA/RAS
Aston U.
ESA/ESOC
IAA
IMVP
FESG
Riga
MCC
BKG
Mendeleevo
NERC/
GFZ/Potsdam
Borowiec
Herstmonceux
GAOUA/Kiev
DGFI
Wettzell
Simeiz
Paris
Graz
Katzively
CERGA/Grasse
AIUB/Zimmerwald
Cagliari
ASI/Matera
San Fernando
Helwan
Riyadh
Maidanak
Komsomolsk
Changchun
Beijing
Simosato
Keystone (4 sites)
Wuhan
Shanghai
Kunming
Hartebeesthoeck*
Yarragadee
Mt. Stromlo
AUSLIG
75°
60°
45°
30°
15°
0°
-15°
-30°
-45°
-60°
-75°
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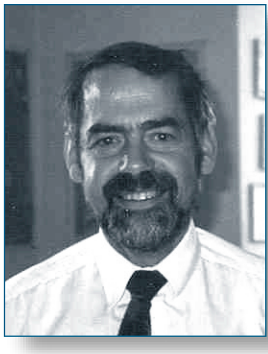
60°
75°
90°
105°
120°
135°
150°
165°

Governing Board



Name: Herman Drewes

Position: Ex-Officio, CSTG President

Affiliation: Deutsches Geodätisches ForschungsInstitut, Germany

Name: John Bosworth

Position: Ex-Officio, ILRS Central Bureau

Affiliation: NASA Goddard Space Flight Center, USA

Name: Michael Pearlman

Position: Ex-Officio, Secretary, ILRS Central Bureau

Affiliation : Harvard-Smithsonian Center for Astrophysics, USA

Name: Werner Gurtner

Position: Appointed, EUROLAS, Networks & Engineering Working Group Coordinator

Affiliation: Astronomical Institute of Berne, Switzerland

Name: Wolfgang Schlüter

Position: Appointed, EUROLAS, Networks & Engineering Working Group Deputy Coordinator

Affiliation: Bundsamt für Kartographie und Geodäsie, Germany

Name: David Carter

Position: Appointed, NASA

Affiliation : NASA Goddard Space Flight Center, USA

Name: John Degnan

Position: Appointed, NASA, Governing Board Chairperson

Affiliation : NASA Goddard Space Flight Center, USA

Name: Yang Fumin

Position: Appointed, WPLTN

Affiliation : Shanghai Observatory, Peoples Republic of China

Name: Hiroo Kunimori

Position: Appointed, WPLTN, Missions Working Group Coordinator

Affiliation: Communications Research Laboratory, Japan

Name: Bob Shutz

Position: Appointed, IERS Representative to ILRS

Affiliation: Center for Space Research, University of Texas, USA

Name: Richard Eanes

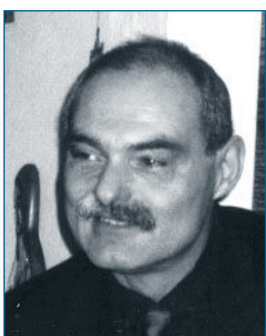
Position: Elected, Analysis Representative

Affiliation: Center for Space Research, University of Texas, USA

Name: Ron Noomen

Position: Elected, Analysis Rep., Analysis Working Group Coordinator

Affiliation: Delft University of Technology, The Netherlands



Name: Wolfgang Seemueller

Position: Elected, Data Centers Representative, Data Formats & Procedures Working Group Deputy Coordinator

Affiliation: Deutsches Geodätisches ForschungsInstitut, Germany

Name: Peter Shelus

Position: Elected, Lunar Rep., Analysis Working Group Deputy Coordinator

Affiliation: University of Texas at Austin, USA

Name: Francois Barlier

Position: Elected, At-Large, Missions Working Group Deputy Coordinator

Affiliation: Centre d'Études et de Recherches Géodynamiques et Astrométrie, France

Name: John Luck

Position: Elected, At-Large, Data Formats & Procedures Working Group Coordinator

Affiliation: Australian Surveying and Land Information Group, Australia