INTERNATIONAL LASER RANGING SERVICE

2001
ANNUAL REPORT

June 2002

Edited by M. Pearlman,
M. Torrence, and C. Noll

Goddard Space Flight Center
Greenbelt, MD 20771 USA

NASA/TP—2002-211610

Available From:

NASA Center for Aerospace Information
7121 Standard Drive
Hanover, MD 21076-1320
Price Code: A17

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Price Code: A10

The NASA STI Program Office … in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the lead center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA's counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.
- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.
- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.
- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.
- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and mission, often concerned with subjects having substantial public interest.
- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized databases, organizing and publishing research results . . . even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at http://www.sti.nasa.gov/STI-homepage.html
- E-mail your question via the Internet to help@sti.nasa.gov
- Fax your question to the NASA Access Help Desk at (301) 621-0134
- Telephone the NASA Access Help Desk at (301) 621-0390
- Write to:
  NASA Access Help Desk
  NASA Center for AeroSpace Information
  7121 Standard Drive
  Hanover, MD 21076–1320

PREFACE

This document is the 2001 Annual Report for the International Laser Ranging Service (ILRS). The individual groups that constitute the entities of the ILRS have provided updates on their activities and have given some insight into their plans for the future. Special attention has been given to the activities of the Working Groups where the users and practitioners work together to help develop the working level plans for implementation.

The contents of this Annual Report also appear on the ILRS website at:

http://ilrs.gsfc.nasa.gov/reports/ilrs_reports/ilrsar_2001.html

The 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. Introductory remarks by CSTG President Dr. Hermann Drewes and the ILRS Chairman's report give a very brief view of the organization and its recent activities.

- Section 1, the Governing Board Report, provides an overview of the ILRS, a history of its origin and establishment, the contribution 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 the 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, the Working Group Reports, includes accomplishments during the past year, activities underway, as well as those planned for the next year. The Working Groups have originated and developed many of the standards and procedures that have been implemented by the service.
- Sections 4,5, and 6 include the Network, Operations Center and Data Center Reports. These sections provide the status of the data chain from the point of data acquisition through archiving.
- Section 7 includes reports for the SLR Analysis and Associate Analysis Centers, as well as the LLR Analysis Centers. These reports provide 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, the website Reference Card and Site Map, the Station Performance Report Card for 2001, a list of institutions contributing to the Annual Report, the list of ILRS Associate Members, a complete list of the ILRS components and a list of acronyms.

In conjunction with the two previous Annual Reports, ILRS 2001Annual Report continues to provide a means of measuring the progress of the ILRS and its components, and to highlight the key items that need to be addressed in the future to make the ILRS a more effective organization.

ACKNOWLEDGEMENTS

The editors would like to acknowledge the following people for their essential contributions to the preparation of the ILRS 2001 Annual Report:

- Van Husson assembled charts and figures for the report.
- John Hazen designed the cover art and the layout for the color pages of the report.

Finally, we would like to thank all of our ILRS colleagues who provided their contributions to this Annual Report.

Table of Contents

Table of Contents

TABLE OF CONTENTS

Table of Contents

THE ILRS:

WITHIN THE NEW STRUCTURE OF IAG AND THE INTEGRATED GLOBAL GEODETIC OBSERVING SYSTEM

The International Association of Geodesy (IAG) decided during its Scientific Assembly, Budapest 2001, to install a new structure starting with the next legislature period 2003–2007. The basic scientific components of this structure are the Commissions, the Services, the IAG Project(s), the Inter-Commission Committee(s) and the Communication and Outreach Branch.

The *Commissions* shall promote the advancement of science, technology and international cooperation in their fields. It was decided to establish the following four Commissions:

- Reference Frames,
- Gravity Field,
- Earth Rotation and Geodynamics,
- Positioning and Applications.

The Services are part of IAG's work and generate products relevant for geodesy and for other sciences and applications. At present the services of IAG are:

- International GPS Service,
- International VLBI Service,
- International Laser Ranging Service,
- International Earth Rotation Service,
- International Gravimetric Bureau,
- International Geoid Service,
- International Center for Earth Tides,
- Permanent Service for Mean Sea Level,
- International Bureau of Weights and Measures (Time Section).

Inter-Commission Committees shall handle well defined, important and permanent tasks involving all commissions. An example is a committee for geodetic theory and methodology.

The *Communication and Outreach Branch* provides the Association with communication, educational/public information and outreach links to the membership, to other scientific associations and to the world as a whole.

IAG Projects serve as the flagships of the Association for a long time period (decade or longer). They are of a broad scope and of highest importance for geodesy. Each IAG Project shall have a Steering Committee consisting of the Project Chair, one member from each Commission, two members-at-large, and the chairs of the Project sub-groups (if any).

A candidate IAG Project "Integrated Global Geodetic Observing System (IGGOS)" was proposed by Reiner Rummel et al. during the IAG Scientific Assembly 2001. It was discussed and approved by the "IAG Committee for the Realization of the New IAG Structure". A planning committee for the project consisting of about twenty persons was installed. This committee will take into account all the work performed by IAG in this area in order to design the objectives, the charter, and the structure of the project. It has to include a close cooperation with the IAG Services, relevant Commissions and Sub-Commissions.

The IGGOS should be seen as geodesy's contribution to the study of the System Earth composed by the solid geosphere, the hydrosphere and the atmosphere. It will provide its findings to interdisciplinary research, governmental agencies and private sectors. In this context one has to consider the existing initiatives in this field, such as the *United Nations (UN)* Integrated Global Observing Strategy (IGOS). The development and implementation of the IGOS is supported by a partnership of several groups of agencies, international research programs and other sponsors. It comprises three Global Observing Systems (G3OS):

- The *Global Terrestrial Observing System (GTOS)* established in 1996 by the Food and Agriculture Organization (FAO) of the UN, the International Council for Science (ICSU), the United Nations Environment Programme (UNEP), the World Meteorological Organization (WMO) and UNESCO.
- The *Global Climate Observing System (GCOS)* installed in 1998 by ICSU, UNEP, WMO, and the Intergovernmental Oceanographic Commission (IOC) of UNESCO;

- The *Global Ocean Observing System (GOOS)* agreed upon by a new Memorandum of Understanding between IOC, WMO, UNEP and ICSU end of 1998.

The purpose of these observing systems is mainly policy oriented rather than dealing with scientific objectives. Their mission is to provide policy-makers with interdisciplinary data they need to detect, locate, understand and warn of changes in the terrestrial ecosystems.

Geodesy (IAG), is very active in some of ICSU's interdisciplinary committees, namely

- Scientific Committee on Antarctic Research (SCAR),
- Committee on Space Research (COSPAR),
- Scientific Committee on the Lithosphere (SCL) with the International Lithosphere Programme (ILP), where IAG has its representatives and common projects, commissions and other activities.

We may thus regard the IAG Project IGGOS as an interface between IAG Commissions and Services on one side, and the ICSU, WMO and UN initiatives on the other side. Within the geodetic community, in particular within IAG, IGGOS shall provide a consistent reference system for all groups of fundamental geodetic parameters:

- Earth rotation parameters (precession, nutation, rotational velocity, pole position),
- Terrestrial position parameters (point coordinates and velocities, surface models - DTM's - and deformations),
- Gravity field parameters (gravity anomalies, height anomalies, geoid, deflections of the vertical, "mean" sea level).

It is understood that reference systems include the definition of a set of geometric and physical parameters necessary for the measurement and the description of the geometry and physical processes within the Earth's system. It shall hereby use consistent standards in geometry (origins, orientations, scales, ...), in physics (speed of light in the media, geocentric gravitational constant, ...), and in dynamics (geopotential and other forces). It shall employ consistent, coordinated observation techniques (e.g., within an Integrated Space Geodetic Network, ISGN) and unique data exchange formats (e.g., SINEX).

These requirements have to be accomplished primarily by the IAG Services. The interaction and coordination of the services' activities is the basic concept of IGGOS. The three pillars of geodesy – geometry and kinematics, Earth orientation and rotation, gravity field and dynamics – shall be combined to a consistent, unified observing system. From this combination a series of new products for Earth sciences shall emerge, such as the feasibility of establishing a global mass balance and the provision of fundamental observables for modeling the system Earth.

The scientific foundations will mainly come from the relevant IAG Commissions. The products to be given to the interdisciplinary community, however, will be provided by the Services. IGGOS is not seen as a new "Super-Service" that generates the products or the scientific results, but it is to coordinate the scientific work and to serve as an interface to the non-geodetic scientific community and to society. It shall strive for the fulfillment of the requirements mentioned above. IGGOS will not be able to operate without the IAG Services.

In this sense, the ILRS plays an important role within the IGGOS concept. Satellite Laser ranging provides unique information for the study of the Earth's system. It gives the best information on the geocentric origin and the scale of the terrestrial reference frame, and it is capable to precisely monitor recent crustal deformations (plate tectonics, isostatic movements, etc.). It is the best technique to connect geometric (station coordinates) and gravity field parameters. It is an important tracking and calibration tool for many Earth observing satellites.

As a conclusion it has to be stated that IGGOS is not thinkable and would not be successful without the intensive engagement of the ILRS. With its decision to join the IGGOS activities, the ILRS supported essentially the new IAG structure and project.

Hermann Drewes

President of the Commission on International

Chairman's Remarks

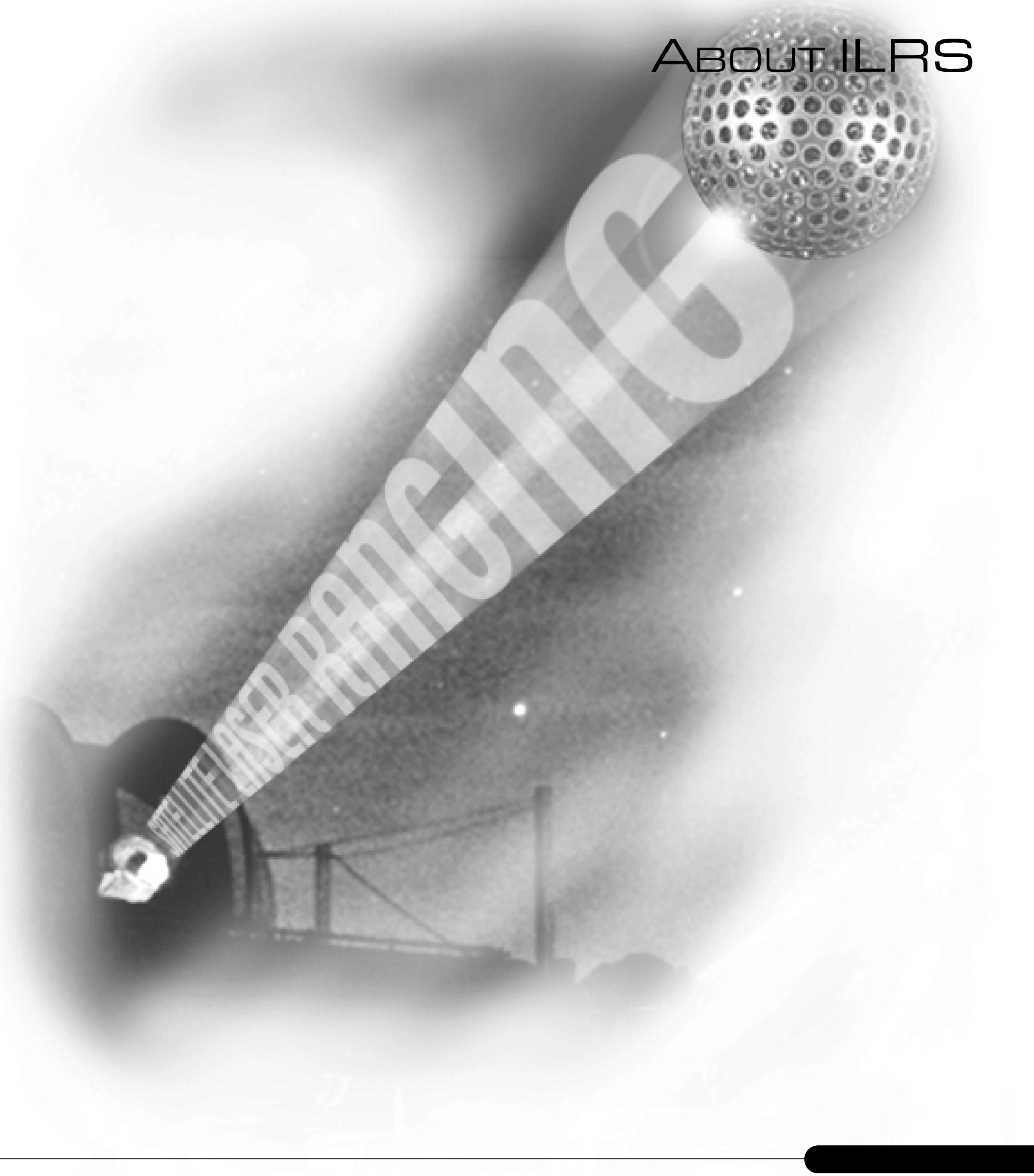
I am pleased to present to our ILRS Associates our second Annual Report covering ILRS activities in the millennium year 2000. The 1999 ILRS Annual Report is also available as hard copy from the Central Bureau or online at the ILRS Web site. Our Secretary, Mike Pearlman, is to be especially commended for his doggedness and determination in bringing these reports together.

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. 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. New Governing Board elections were held last summer and the new Board was installed in November 2000 at the 12th International Workshop on Laser Ranging in Matera, Italy. Due to recent changes in the makeup of the IERS, the ILRS representation on the IERS Directing Board was increased from one to two voting members. The ILRS Governing Board has designated our Analysis Coordinator, Ron Noomen, and our Lunar Laser Ranging Representative, Peter Shelus, as the official ILRS delegates to the IERS Directing Board.

In creating the structure for the new ILRS, the Working Groups (WG's) were intended to be the focal points for most Governing Board activities. 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 material to the Central Bureau for inclusion in the knowledge databases. I am pleased to report that the WG's continue to attract talented people from the general ILRS membership who have contributed greatly to the success of these efforts. The Missions WG has formalized and standardized the mission documentation required to obtain ILRS approval for new missions and campaigns. They continue to work with new missions and campaign sponsors to develop and finalize tracking plans and to establish recommended tracking priorities. The Data Formats and Procedures WG has been tightening up existing formats and procedures, rectifying anomalies, providing standardized documentation through the web site, and setting up study subgroups and teams to deal with more complicated or interdisciplinary issues. The Networks and Engineering WG has (1) developed the new ILRS Site and System Information Form which is being distributed to the stations to keep the engineering database current, (2) provided a new online satellite-link analysis capability for system design and performance evaluation, and (3) initiated the development of the ILRS technology database. The Analysis WG has been working with the ILRS Analysis Centers to develop a unified set of analysis products presented in the internationally accepted SINEX format. Three associated pilot programs are underway to assess differences among analysis products from the different centers. The Signal Processing Ad-Hoc WG is working on improved center-of-mass corrections and signal processing techniques for SLR satellites. More detailed information on the activities of the Working Groups and the Central Bureau can be found elsewhere in this volume. ILRS Associates who wish to volunteer their time or ideas in support of any of these organizations are encouraged to contact the Central Bureau or the appropriate WG Coordinator.

John J. Degnan
ILRS Governing Board Chairperson
Code 920.3, Geoscience Technology Office
NASA Goddard Space Flight Center
Greenbelt, MD 20771 USA

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:

The ILRS was established as a service of the International Association of Geodesy (IAG) in 1998. Prior to the formation of the ILRS, international SLR activities were coordinated under IAG Commission VIII—the International Coordiantion of Space Techniques for Geodesy and Geodynamics (CSTG). The ILRS is one of three services, with the IGS (International GPS Service) and the IVS (International VLBI Service for Geodesy and Astrometry), in the IAG that support scientific measurements.

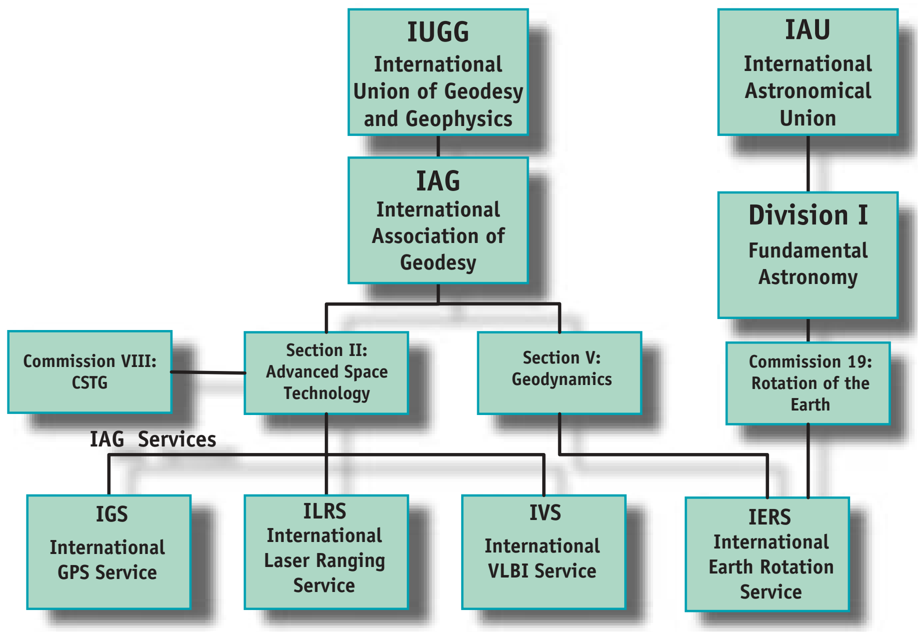
The ILRS develops (1) the standards and specifications necessary for product consistency and (2) the priorities and tracking strategies required to maximize network efficiency. The service collects, merges, analyzes, archives and distributes satellite and lunar ranging data to satisfy a variety of scientific 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 publicaly available.

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

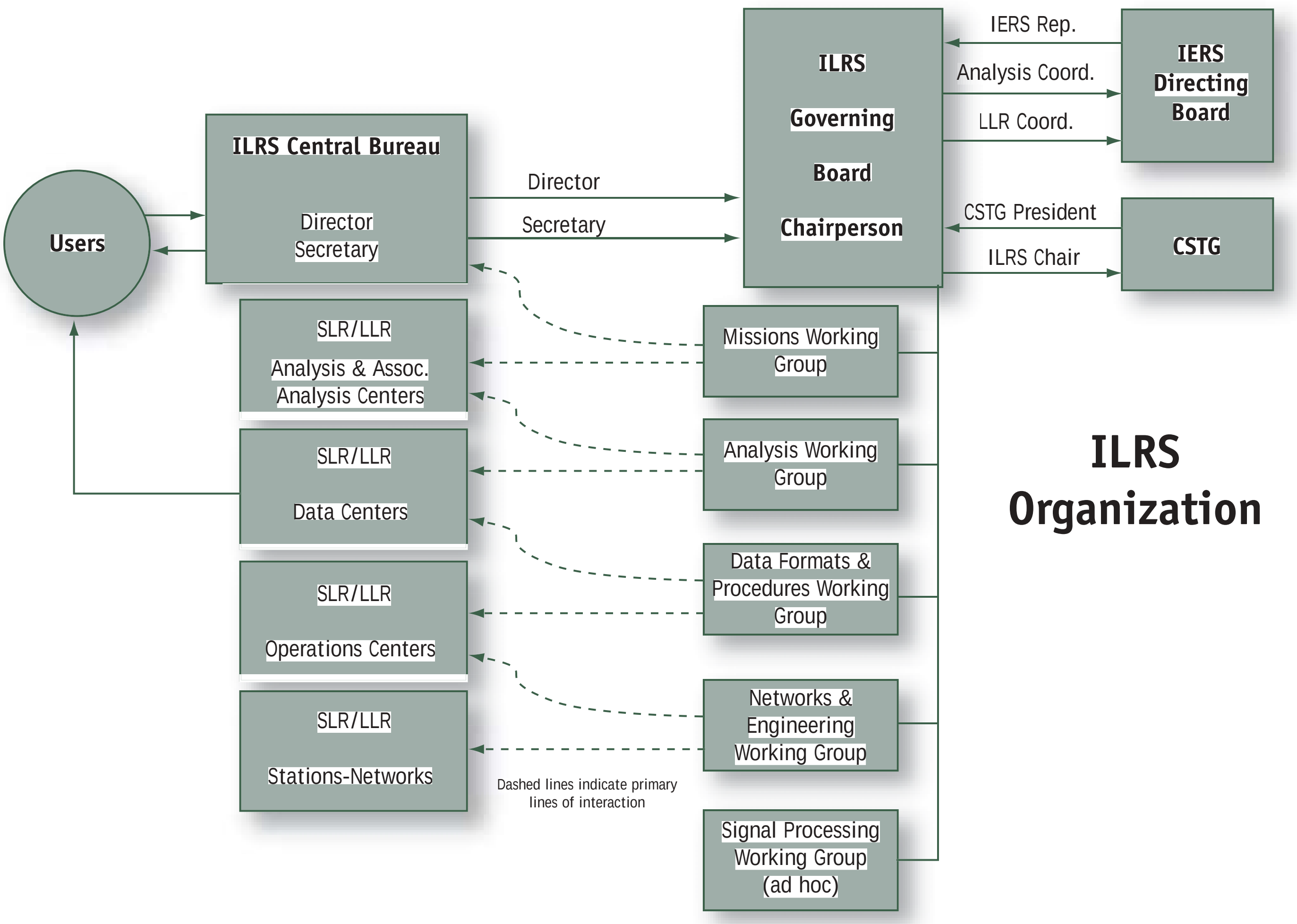


Structure:

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.



ILRS Organization

This page deliberately left blank.

ILRS Component Map

FFI
Metsahovi
ESA/ESOC
IAA
IA/RAS
Newcastle U.
FESG/IFE
IMVP
Riga
MCC
BKG
GFZ/Potsdam
Borowiec
Mendeleevo
RC/Herstmonceux
Wettzell
GAOUA/Kiev
DGFI
Graz
Simeiz
Paris
Katzively
CERGA/Grasse
Cagliari
CLG/BAS
San Fernando
ASI/Mate
AIUB/Zimmerwald
Helwan
Riyadh
Maidanak
Komsomolsk
Changchun
Beijing
CRL
NASDA
Simosato
Keystone (4 sites)
Wuhan
Shanghai
Kunming
Hartebeesthoek
Yarragadee
Mt. Stromlo
GA/NMD
Mobile Systems: FTLRS-1 (France)
TIGO (Germany)
TROS (China)

Governing Board

Name: Herman Drewes

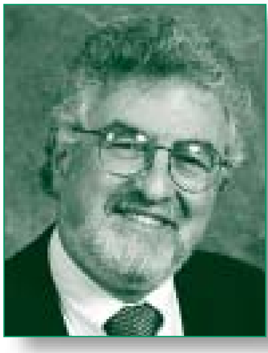
Position: Ex-Officio, CSTG President

Affiliation: Deutsches Geodätisches ForschungsInstitut, Germany

Name: Carey Noll

Position: Ex-Officio, Secretary ILRS Central Bureau

Affiliation: NASA Goddard Space Flight Center, USA



Name: Michael Pearlman

Position: Ex-Officio, Director, 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

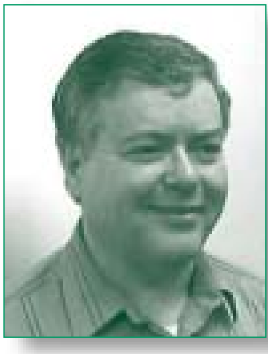
Position: Appointed, EUROLAS

Affiliation: Bundsamt für Kartographie und Geodäsie, Germany

Name: David Carter

Position: Appointed, NASA Missions Working Group Deputy Coordinator

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: Graham Appleby

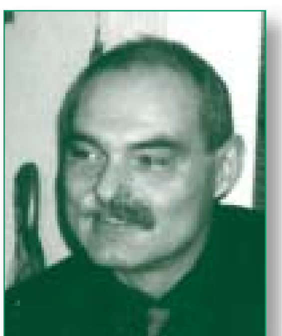
Position: Analysis Center Representative, Signal Processing Working Group Coordinator

Affiliation: Natural Environment Research Council (NERC), UK

Name: Ron Noomen

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

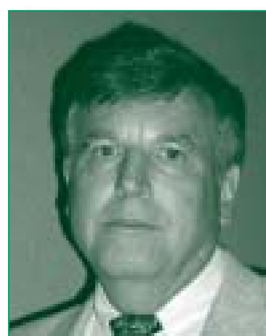
Affiliation: Delft University of Technology, The Netherlands



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: Georg Kirchner

Position: Elected, At Large Network and Engineering Working Group Deputy Coordinator

Affiliation: Austrian Academy of Sciences, Austria

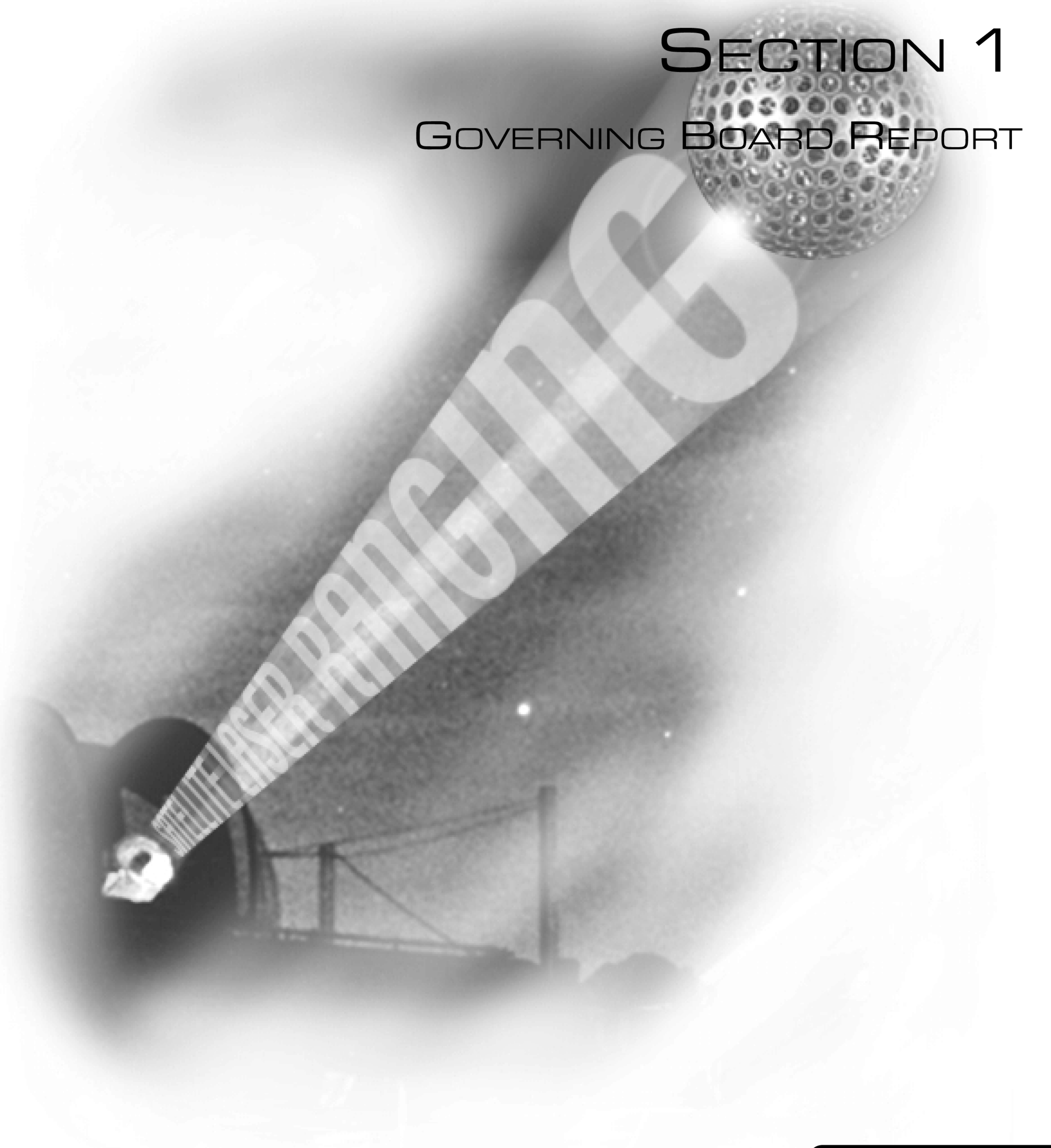
Name: John Luck

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

Affiliation: Australian, Surveying and Land Information Group, Australia

Section 1

Governing Board Report



SECTION 1 - GOVERNING BOARD REPORT

John Degnan, *NASA, Goddard Space Flight Center*

1.0 INTRODUCTION

The Governing Board (GB) is responsible for the general direction of the service. It defines official ILRS policy and products, determines satellite-tracking priorities, develops standards and procedures, and interacts with other services and organizations. There are 16 members of the Governing Board (GB) - three are ex-officio, seven are appointed, and six are elected by their peer groups (see Table 1.0-1). The current Board members were appointed or elected for a two-year term in the summer of 2000 and were installed in November 2000 at the 12th International Workshop on Laser Ranging in Matera, Italy. Table 1.0-1 lists the current GB membership, their nationality, and special function (if any) on the GB. The new board will be elected in the summer of 2002 and installed at the 13th International Workshop to be held in Washington DC during the week of October 7-11, 2002.

Table 1.0-1. ILRS Governing Board (as of December 2001).

Member	Position	Country
Hermann Drewes	Ex-Officio, CSTG President	Germany
Michael Pearlman	Ex-Officio, Director ILRS Central Bureau	USA
Carey Noll	Ex-Officio, Secretary, ILRS Central Bureau	USA
Werner Gurtner	Appointed, EUROLAS, Networks & Engineering WG Coordinator	Switzerland
Wolfgang Schlueter	Appointed, EUROLAS	Germany
David Carter	Appointed, NASA, Missions WG Deputy Coordinator	USA
John Degnan	Appointed, NASA, Governing Board Chairperson	USA
Yang FuMin	Appointed, WPLTN	PRC
Hiroo Kunimori	Appointed, WPLTN, Missions WG Coordinator	Japan
Bob Schutz	Appointed, IERS Representative to ILRS	USA
Graham Appleby	Elected, Analysis Rep., Signal Processing WG Coordinator	UK
Ron Noomen	Elected, Analysis Rep., Analysis WG Coordinator	Netherlands
Wolfgang Seemueller	Elected, Data Centers Rep., Data Formats & Procedures WG Deputy Coordinator	Germany
Peter Shelus	Elected, Lunar Rep., Analysis WG Deputy Coordinator	USA
Georg Kirchner	Elected, At-Large, Networks and Engineering WG Deputy Coordinator	Austria
John Luck	Elected, At-Large, Data Formats & Procedures WG Coordinator	Australia

Within the GB, permanent (Standing) or temporary (Ad-Hoc) Working Groups (WG's) carry out policy formulation for the ILRS. At its creation, the ILRS GB established four Standing WG's: (1) Missions, (2) Data Formats and Procedures, (3) Networks and Engineering, and (4) Analysis. In 1999, an additional Ad-Hoc Signal Processing WG was organized to provide improved satellite range correction models to the analysts. The Working Groups are intended to provide the expertise necessary to make technical decisions, to plan programmatic courses of action, and are responsible for reviewing and approving the content of technical and scientific databases maintained by the Central Bureau. All GB members serve on at least one of the four Standing Working Groups led by a Coordinator and Deputy Coordinator.

1.1 ILRS Network

The current ILRS Network is shown in Figure 1.1-1. Traditionally the network has been strong in the US, Europe, East Asia, and Australia. Through international partnerships, the global distribution of SLR stations is now improving, especially in the Southern Hemisphere. NASA, working in cooperation with CNES and the University of French Polynesia has established SLR operations on the island of Tahiti with MOBLAS-8. In cooperation with the South African Foundation for Research Development (FDR), NASA has relocated MOBLAS-6 to Hartebeesthoek (which already has VLBI, GPS, and DORIS facilities) to create the first permanent Fundamental Station on the African continent. Both systems are operational. Operations at the new Australian station at Mt. Stromlo, which replaced the older Orroral site near Canberra, are going extremely well in terms of both data quantity and quality.

The NASA TLRS-3 system at Universidad de San Agustin in Arequipa, Peru has carried the total SLR tracking load for South America in recent years. However, in early 2002, BKG (Germany) will began operations of the multi-technique Totally Integrated Geodetic Observatory (TIGO) system in Concepcion, Chile. The TIGO- with SLR, VLBI, GPS and absolute gravimetry techniques will be the only Fundamental Station in South America. In Argentina, NASA has been discussing a possible transfer of TLRS-4 to the University of La Plata. A possible joint Chinese-Argentine SLR station at the San Juan Observatory in western Argentina, with SLR equipment furnished by the Beijing Astronomical Observatory, is also in negotiations.

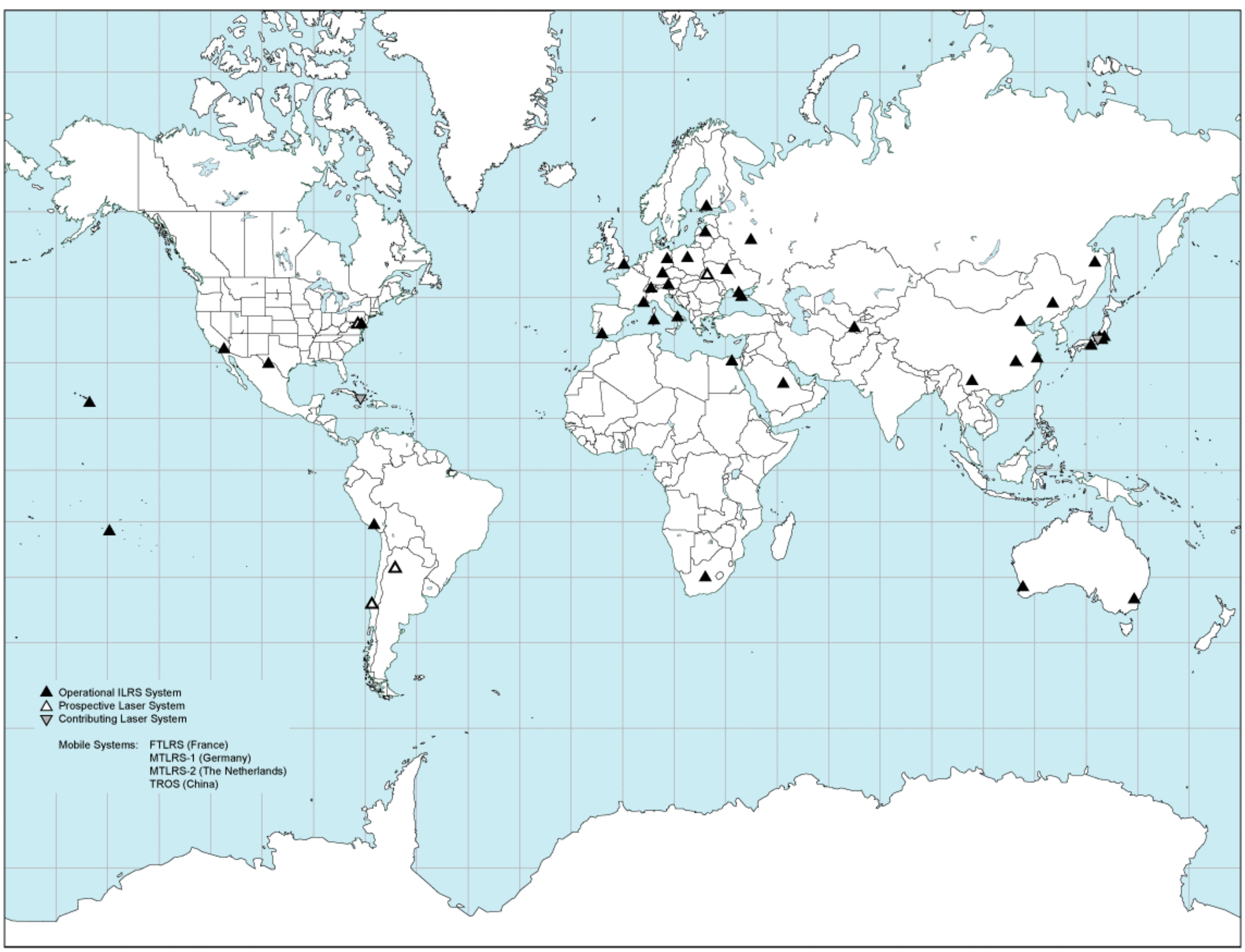


Figure 1.1-1. The ILRS Network.

The Peoples' Republic of China has made substantial investment in SLR stations and technology over the past several years. The SLR station in Kunming was recently re-established, bringing the total number of Chinese permanent sites to five (Shanghai, Changchun, Wuhan, Beijing, and Kunming). The data quality and quantity from the permanent Chinese stations continue to improve, most notably at Changchun. The Wuhan SLR station has been recently moved to a site outside the city where there is significantly better atmospheric seeing. A Chinese mobile TROS system has occupied sites in Lhasa and Urumqi as part of a national geodetic program. Construction is nearing completion on second Chinese mobile SLR station. The new Russian SLR station started operations near Moscow in 1999, and permission is being requested from the Russian government to integrate it into international SLR operations. A Russian SLR station in Novosobirsk has recently applied for ILRS membership.

In Japan, The Communications Research Laboratory (CRL) in Tokyo has closed its four Keystone sites in the Tokyo area. The Simosato site, operated by the Japanese Hydrographic Institute, continues to provide data in this technically highly interesting region. The Japanese Space Agency, NASDA, is also building a new state-of-the-art SLR station, Global and High Accuracy Trajectory Determination System (GUTS), to be located in Tanagashima at the southern tip of Japan.

Sites in the United States and Europe have been relatively stable over the past several years, with efforts primarily directed at improving overall performance or reducing the cost of SLR operations. After a long period of technical problems and engineering upgrade, the NASA HOLLAS station, operated on Mt. Haleakala by the University of Hawaii, has begun to make a comeback following the installation of a new tracking mount and controller. The data output from this geographically important station is slowly returning to earlier levels. This has been especially important as the output from the joint NASA/CNES partnership station in Tahiti has unexpectedly dropped in the past year due to an unfortunate turnover of station personnel. Both CNES and the University of the Pacific are aggressively addressing the personnel issue in Tahiti, and it is hoped that station performance will soon return to earlier levels. The combined problems in Hawaii and Tahiti have impacted the amount of laser tracking data from the Central Pacific during this reporting period. Fortunately, two of the stations on opposite sides of the Pacific - the Australian site at Mt. Stromlo and the NASA Moblas 4 site in California - continue to rank among the best in the world with regard to both data quality and quantity.

The new state-of-the-art Matera Laser Ranging Observatory (MLRO), which was showcased at the 2000 Matera workshop, has demonstrated a lunar ranging capability and has been equipped with a state-of-the-art two color streak camera receiver. The system is expected to be declared fully operational soon following a rather lengthy period in engineering status. The new French Transportable Laser Ranging System (FTLRS), which was redesigned to operate at the 532 nm wavelength, has established operations on the island of Corsica to support the calibration of the new Joint CNES/NASA JASON altimetric mission as well as other oceanographic missions as they overfly the Mediterranean. In the Ukraine a new SLR site is operating in Kiev, and an additional station is being established in Lviv.

The unmanned SLR2000 prototype is nearing completion at NASA and field tests are expected to begin in Fall 2002. SLR2000 will be showcased at the upcoming Thirteenth International Workshop on Laser Ranging to be held in Washington DC during the week of October 7-11, 2002. The Workshop is jointly hosted by the NASA Goddard Space Flight Center and the Smithsonian Institution.

1.2 ILRS Tracking Priorities and Campaigns

The ILRS is tracking 25 targets, including passive geodetic (geodynamics) satellites, Earth remote sensing satellites, navigation satellites, engineering missions, and lunar reflectors (see Tables 1.2-1 and 1.2-2). Tracking of the South African SUNSAT remote sensing mission was terminated at its end of life. Tracking on Westpac also ceased. Three GLONASS (78, 80, and 84) satellites are being tracked in continuing support of the IGLOS campaign.

The ILRS assigns satellite priorities in an attempt to maximize data yield on the full satellite complex while at the same time placing greatest emphasis on the most immediate data needs. Priorities provide guidelines for the network stations, but stations may occasionally deviate from the priorities to support regional activities or national initiatives and to expand tracking coverage in regions with multiple stations. Tracking priorities are set by the

Governing Board, based on application to the Central Bureau and recommendation of the Missions Working Group.

Table 1.2-1. ILRS Earth Satellite Tracking Priorities (as of December 31, 2001).

Priority	Satellite	Sponsor	Altitude (Km)	Inclination	Comments
1	CHAMP	GFZ	470	87.3	Gravity research
2	GFO-1	US Navy	790	108.0	Altimeter POD/calibration no other tracking technique, Upgraded to ILRS Mission Apr 2001
3	ERS-2	ESA	800	98.6	Altimeter calibration, PRARE backup
4	TOPEX/Poseidon	NASA.CNES	1,350	66.0	Altimeter calibration, DORIS and GPS backup
5	Starlette	CNES	815 — 1,100	49.8	Geodetic, no other tracking technique available
6	Stella	CNES	815	98	Geodetic, no other tracking technique available
7	Meteor-3M	NASA/IPIE, Russia	1020	99.64	Retroreflector research, tracking by only 2 NASA sites
9	Beacon-C	NASA	950 — 1,300	41	Upgraded to ILRS Mission 1 Jan 2001
9	Reflector	ROSAVIA/COS	1020	99.6	Launch 10 Dec 2001 9 month campaign
10	Ajisai	NASDA	1,485	50.0	Geodetic, no other tracking technique available
11	LAGEOS-2	ASI/NASA	5,625	52.6	Geodetic, no other tracking technique available
12	LAGEOS-1	NASA	5,850	109.8	Geodetic, no other tracking technique available
13	Etalon 1	RSA	19,100	65.3	Geodetic, no other tracking technique available, Etalon campaign began 1 Apr 2001
14	Etalon 2	RSA	19,100	65.2	Geodetic, no other tracking technique available
15	GLONASS 78	RSA/IGLOS	19,100	65	Positioning POD enhancement, replaced G72 6/29/00
16	GLONASS 80	RSA/IGLOS	19,100	65	Positioning POD enhancement, replaced G70 10/20/99
17	GLONASS 84	RSA/IGLOS	19,100	65	Positioning POD enhancement, replaced G7a 2/22/01
18	GPS 35	US Air Force	20,100	54.2	Positioning POD enhancement
19	GPS 36	US Air Force	20,100	55.0	Positioning POD enhancement

Table 1.2-2. ILRS Lunar Reflector Tracking Priorities (as of December 31, 2001).

Priority	Lunar Targets	Sponsor
1	Apollo 15	NASA
2	Apollo 11	NASA
3	Apollo 14	NASA
4	Luna 21	RSA

The ILRS conducted a number of campaigns during 2001. Tracking on Beacon-C continued to support gravity field improvements in preparation for the upcoming Gravity and Climate Experiment (GRACE). The US Navy's GFO-1 oceanographic satellite was approved by the GB for intense tracking due to a failure in the four redundant GPS receivers and is now totally reliant on SLR for its orbit. The highly elliptical orbit of the Japanese LRE mission presented new technical challenges to the ILRS network. At the request of the ILRS Analysis Working Group, Etalon 1 and 2 were elevated in tracking priority above the other high altitude satellites, GPS and GLONASS, to better understand the ultimate capabilities of SLR in measuring Earth Orientation Parameters (EOP). Another campaign was scheduled to test two new retroreflector packages onboard the Russian Meteor-3M and companion Reflector satellite. Meteor-3M carries an experimental retroreflector, which is the optical equivalent of the Luneberg lens used in microwave systems. It consists of two concentric glass balls of different index of refraction with one half coated with a reflective coating. Although originally intended as a six week campaign experiment, the immediate failure of the onboard GPS/GLONASS receiver following launch resulted in a request to the ILRS for routine tracking status in support of the NASA SAGE mission. The Reflector satellite consists of several small arrays placed at different positions and orientations to allow the measurement of spacecraft attitude. Tests were also conducted to verify the tracking capability on STARSHINE 3.

Since several remote sensing missions have suffered failures in their active tracking systems or have required in-flight recalibration, the ILRS has encouraged new missions with high precision orbit requirements to include retroreflectors as a fail-safe backup tracking system, to improve or strengthen overall orbit precision, and to provide important intercomparison and calibration data with onboard microwave navigation systems.

1.3 Upcoming Missions

At one time, the main task of the international SLR Network was the tracking of dedicated geodetic satellites (LAGEOS, Starlette, etc.). Although we have had requests to revive tracking on older satellites already in orbit (e.g. Beacon-C) to further refine the gravity field with improved accuracy laser data, new requests for tracking are now coming mainly from active satellite missions. The tracking approval process begins with the submission of a Missions Support Request Form, which is accessible through the ILRS web site. The form provides the ILRS with the following information: a description of the mission objectives; mission requirements; responsible individuals, organizations, and contact information; timeline; satellite subsystems; and details of the retroreflector array and its placement on the satellite. This form also outlines the early stages of intensive support that may be required during the initial orbital acquisition and stabilization and spacecraft checkout phases. A list of upcoming space missions that have requested ILRS tracking support (as of 22 January 2002) is summarized in Table 1.3-1 along with their sponsors, intended application, projected launch dates, mission duration, and ILRS status.

Once tracking support is approved by the Governing Board, the Central Bureau works with the new missions to develop a Mission Support Plan detailing the level of tracking, the schedule, the points of contact, and the channels of communication. New missions normally receive very high priority during the acquisition and checkout phases and are then placed at a routine priority based on the satellite category and orbital parameters. After launch, New Mission Reports with network tracking statistics and operational comments are issued weekly. The Central Bureau monitors progress to determine if adequate support is being provided. New mission sponsors (users) are requested to report at the ILRS Plenary meetings on the status of ongoing campaigns, including the responsiveness of the ILRS to their needs and on progress towards achieving the desired science or engineering results.

Table 1.3-1. New Missions and Campaigns Planned for 2001-2002).

Mission Name	Support Requester	Application	Planned Launch Date	Mission Duration	Received Mission Request Form	Received ILRS GB approval
STARSHINE 2	NASA, NRL, etc.	Atomspheric Drag, Educational outreach	Nov. 2001	5 mon.	Yes	Approved conditionally for limited testing only.
Jason-1	CNES/NASA France/USA	Environmental change	Dec. 2001	5 yrs	Yes	Yes
ENVISAT-1	ESA Europe	Environmental change	Mar. 2002	5 yrs	Yes	No
GRACE	NASA GFZ	Gravity field modeling	Mar. 2002	5 yrs	Yes	Yes
ICESat (GLAS)	NASA USA	ice level and ocean surface topography	Dec. 2002	3-5 yrs	Yes	Yes
ADEOS-II	NASDA Japan	Ocean circulation; atmosphere-ocean interaction	Dec. 2002	3 yrs	Yes	Yes
Gravity Probe B (GP-B)	NASA-JPL USA	Relativity	Apr. 2003	1-2 yrs	Yes	Yes
IRS-P5	ISRO	Experimental	Late 2003	5 yrs	No	No
ALOS	NASDA	Altimeter calibration	Jul/Aug 2003	3 yrs	No	No
ETS-VIII	NASDA	Time transfer	Jul/Aug 2003	3 yrs	No	No
CryoSat	ESA	Sea Ice, Ice Cap	Apr/May 2004	3.5 yrs	Yes	Awaiting MWG recommendation
VCL	NASA	Laser Altimeter	TBD	18 mon.	Yes	No

1.4 MEETINGS AND REPORTS

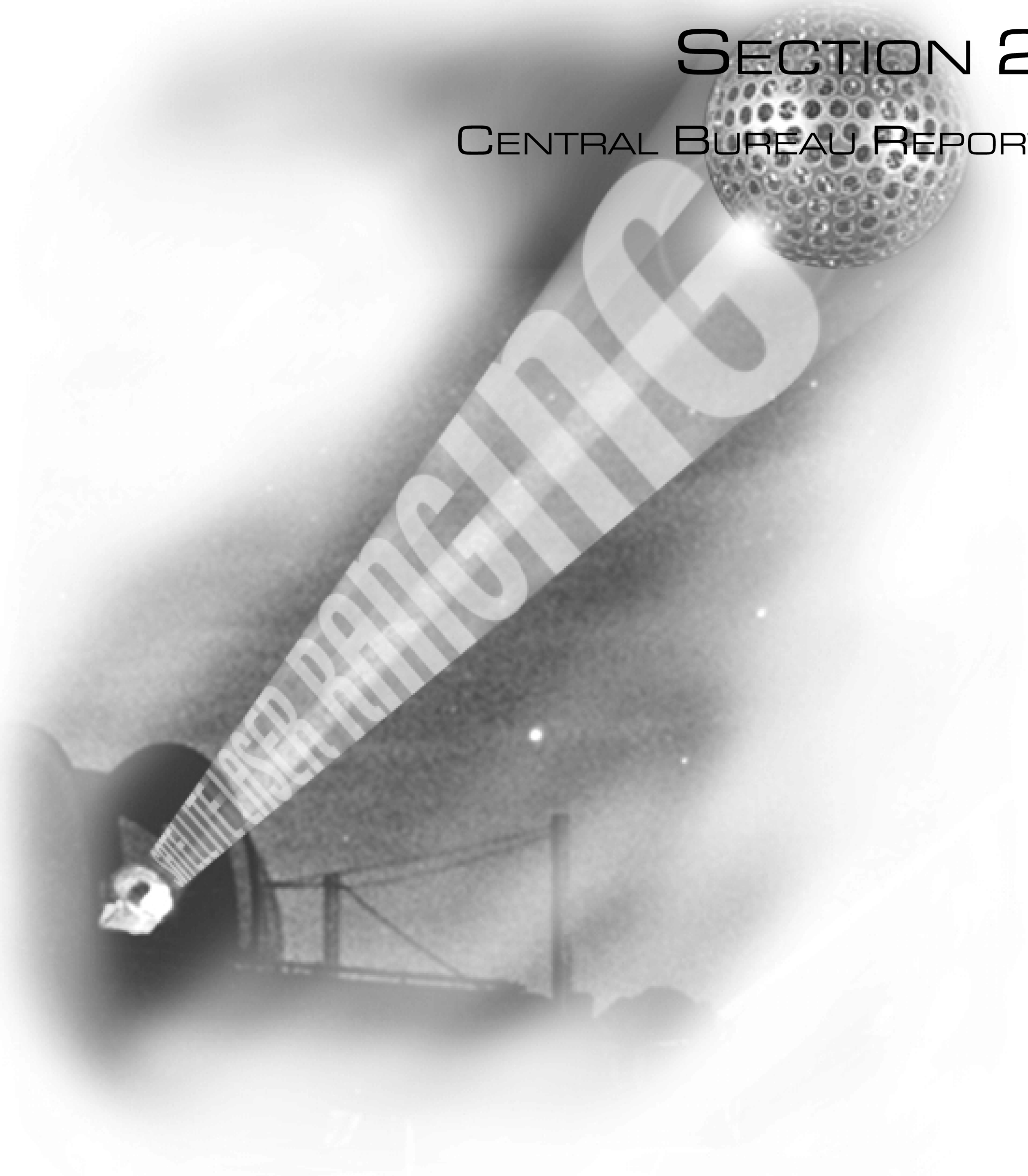
The ILRS organizes semiannual meetings of the Governing Board and General Assembly, which is open to all ILRS Associates and Correspondents. The 6th ILRS General assembly was held on 28 March 2001 in Nice, France, in conjunction with the EGS Symposium. Detailed reports from past meetings can be found at the ILRS web site.

The 7th ILRS General Assembly was scheduled to be held at the Centre de Congres Pierre Baudis in Toulouse, France, on Friday morning, 21 September 2001, in conjunction with the SPIE/Europto Symposium on Remote Sensing (September 17-21, 2001). Open ILRS-sponsored Working Group sessions and a calibration workshop were also scheduled. Unfortunately, the events of 9/11 caused all of these ILRS meetings to be cancelled at the last minute. A special Joint ILRS/WPLTN symposium in Riyadh, Saudi Arabia, on the following Sunday and Monday (September 23-24) was also cancelled. As a result, the 7th ILRS General Assembly was postponed until the next EGS Symposium during the week of 22 April 2002. The 8th ILRS General Assembly will be held in conjunction with the 13th International Workshop on Laser Ranging to be held in October 2002 in Washington DC.

ILRS Analysis Center reports and inputs are used by the Central Bureau for weekly review of station performance and to provide feedback to the stations when necessary. Special weekly reports on on-going campaigns are issued by email. The CB also generates Quarterly Performance Report Cards and posts them on the ILRS web site. The Report Cards evaluate data quantity, data quality, and operational compliance for each tracking station relative to ILRS minimum performance standards. A catalogue of diagnostic methods, for use along the entire data chain starting with data collection at the stations, has emerged from this process and will be made available on the ILRS web site. The evaluation process has been helpful in comparing results from different Analysis and Associate Analysis Centers, a role soon to be assumed by the Analysis Working Group.

SECTION 2

CENTRAL BUREAU REPORT



Section 2 - Central Bureau Report

2.0 Introduction

Michael Pearlman, *Harvard-Smithsonian Center for Astrophysics*

The Central Bureau (CB) is responsible for the daily coordination and management of ILRS activities to ensure ILRS objectives are achieved consistently and continuously. It facilitates communications and information transfer and promotes ILRS standards. The CB monitors network data quality and quantity to ensure mission requirements are being achieved. It maintains the ILRS Web site and ILRS documentation (e.g. bibliography, meeting minutes, administrative and technology databases). The CB organizes meetings and workshops and also the completion of the ILRS Annual Report. The Science Coordinator and Analyst Specialists, within the CB, strengthen the ILRS interface with the scientific community to promote Satellite and Lunar Laser Ranging goals, capabilities, and accomplishments, and to lead efforts to ensure that ILRS data products meet the needs of the user community.

2.1 Status and Activities

Van Husson, *Honeywell Technology Solutions, Inc.*

Organization

The Central Bureau (cb@ilrs.gsfc.nasa.gov), funded by NASA, provides the necessary skill mix to support the technical and administrative services required by the ILRS. The Central Bureau staff includes personnel from NASA GSFC, the Harvard-Smithsonian Center for Astrophysics (CFA), Honeywell Technology Solutions Inc (HTSI), Raytheon Information and Technology and Scientific Services (RITSS), and the three regional networks (i.e. NASA, EUROLAS, WPLTN):

Table 2.1-1. Central Bureau staff

Name	Title	Institution
Michael Pearlman	Director	CFA
Carey Noll	Secretary	NASA GSFC
Steve Klosko	Science Coordinator	Raytheon ITSS
Van Husson	SLR Systems Specialist	HTSI
Peter Dunn	Analysis Specialist	Raytheon ITSS
Mark Torrence	Analysis Specialist	Raytheon ITSS
Scott Wetzel	Operations Specialist	HTSI
Julie Horvath	Operations Specialist	HTSI
Hoai Vo	Web Master	HTSI
Erricos Pavlis	Analysis Specialist	JCET
Georg Kirchner	EUROLAS Network Coordinator	Austrian Academy of Sciences
Hiroo Kunimori	WPLTN Network Coordinator	CRL
David Carter	NASA Network Coordinator	NASA GSFC

ACTIVITIES

During the last year, the CB has worked with ILRS entities and their members to add or enhance services that were deemed necessary. Many of these services were formulated as joint action items between one or more Working Groups and the Central Bureau. Some of the key accomplishments for the last year include:

- monthly on-line campaign reports including graphics;
- proposal for Qualification for ILRS Station s by performance;
- the ILRS 2000 Annual Report;
- enhanced global performance report card;
- ILRS site tie analysis;
- coordinated new mission support requirements;
- updated predictions survey; and
- ILRS Web site by adding the services mentioned above.

Others still in process include implementation of:

- an automated quality control (i.e. format and data integrity) of site log information and development of a automatic master site description data base;
- additional enhancements to the Web site through a better search engine, and standardized navigation bars, and breadcrumbs;
- an enhanced search capability of the ILRS Bibliography using keywords; and
- an SLR Bias File of historical recoverable biases and known problem data.

Since the inception of the Central Bureaus, a core group of its members has met monthly to monitor progress on its action items, to assess station performance and interactions with other entities, and to monitor the status of Working Group activities.

MEETINGS

The Central Bureau organized the ILRS General Assemblies in Nice, France in March 2001 and Toulouse, France in September 2001, which was cancelled. A presentation on the ILRS was given at the IAG Scientific Assembly in Budapest, Hungary in September 2001.

CHALLENGES

Although many tasks were accomplished by the end of 2001, near and long term challenges for the Central Bureau include:

- strengthening the promotion of SLR and LLR goals, capabilities and accomplishments;
- encouraging and assisting stations and analyst centers to meet minimum performance criteria;
- continuing the maturation of the ILRS Web site and supporting data bases;
- encouraging and assisting stations in their timely maintenance of their site information logs and local survey ties;
- encouraging advancements in SLR technology to achieve millimeter accuracy; and
- incorporating GPS data into the regular prediction cycle.

2.2 Network Performance Evaluation

Van Husson, *Honeywell Technology Solutions, Inc.*

Activities

The CB is responsible for network performance evaluation and coordination of data problem resolution. The CB analysis team maintains and develops diagnostics tools using data processing parameters provided in the normal point data along with orbital analysis results from the Analysis Centers (ACs).

When the diagnostics indicate a problem, an investigation is initiated. The investigation involves the coordination with the ACs, station operations and station engineering. The data problem is documented and communicated to the user community. If the data is recoverable, the data will either be re-supplied or a data correction algorithm will be provided and will appear in the master SLR Bias File.

The CB generates the quarterly Network Performance Report Card posted on-line at:

http://ilrs.gsfc.nasa.gov/stations/performance_statistics/index.html

The report card contains site metrics, which are assessed versus established ILRS performance goals in data quantity, data quality, and operational compliance. These goals have evolved from guidelines presented at the Shanghai 10th International Workshop on Laser Ranging in November 1996. The last report card in 2001 appears in Section 8.4.

Challenges

The CB will continue to enhance its systematic bias detection capability to the sub-cm level. This will greatly assist the ILRS as it pursues mm accuracy. These improvements include:

- automated comparison of analysis center results;
- automated comparison of biases from sites in close proximity;
- automated meteorological data integrity checks at finer resolutions; and
- an SLR Bias file (knowledge base of bias corrections and *bad* data)

The CB will continue to push the responsibility of data quality control from the analyst centers to the stations. To accomplish this objective, the CB will continue to provide technical assistance and ongoing training via workshops and the ILRS Web site.

2.3 Mission Priorities

The ILRS satellite priorities as of December 31, 2001 are given in Tables 1.2-1 and 1.2-2.

ILRS tracking priorites decrease with increasing orbital altitude and orbital inclination (at a given altitude). Priority of some satellites may then be increased to intensify support for active missions (such as altimetry), special campaigns, or post-launch intensive tracking phases. Priorites may also be slightly reordered to accommodate increased importance to the analysis community.

During 2001, at the request of IGLOS GLONASS 72 and 79 were replace with GLONASS 78 and 84 on the ILRS tracking roster.

Tracking priorities are formally reviewed semiannually at the ILRS General Assembly Meetings. Updates are made as necessary at the discretion of the Governing Board.

2.4 NETWORK CAMPAIGNS

INTRODUCTION

The ILRS is responsible for the tasking and coordinating of special SLR tracking campaigns that are requested by users, supported by the Missions Working Group, and approved by the ILRS Governing Board. A user can request a tracking campaign through the ILRS Central Bureau by first completing the on-line SLR Mission Support Request Form accessible through the ILRS Web site at:

http://ilrs.gsfc.nasa.gov/satellite_missions/ilrssup.html

The form provides the ILRS with a description of the mission objectives; mission requirements; responsible individuals, organizations, and contact information; timeline; satellite subsystems (including details of the retroreflector array and its placement on the satellite).

NEW MISSIONS IN 2001

METEOR-3M

The Meteor-3M spacecraft, launched on December 10th, 2001, is an advanced model of the Meteor spacecraft that was developed over 30 years ago. The payload includes SAGE III (Strategic Aerosol and Gas Experiment) and other instruments designed to measure temperature and humidity profiles, clouds, surface properties, and high energy particles in the upper atmosphere. The SAGE III/Meteor-3M satellite mission is a joint partnership between NASA and the Russian Aviation and Space Agency (RASA). SAGE III is a gyrating spectrometer that uses ultraviolet/visible observations to measure the vertical structure of aerosols, ozone, water vapor, and other important trace gases in the upper troposphere and stratosphere. Meteor-3M was also designed for flight testing of the novel-type spherical retroreflector for precise laser ranging.

SLR will be used for precise orbit determination and retroreflector research. Two NASA systems and one Russian system are currently tracking Meteor-3M for a short retroreflector experiment prior to the SAGE III activation. A request for full ILRS support will be made in early 2002.

Additional information can be found on the ILRS Web site at:

http://ilrs.gsfc.nasa.gov/satellite_missions/list_of_satellites/meteor3m/

CAMPAIGNS COMPLETED IN 2001

Two campaigns were completed in 2001

Table 2.4-1 ILRS Campaigns Completed in 2001

Campaign	Initiated by	Start Date	End Date	Purpose	No. Passes
BE-C*	Univ. of Texas Minkang Cheng	July 15, 1999	Dec. 31, 2001	Gravity field modeling	6214
GFO-1*	NASA Frank Lemoine	Apr. 22, 1998	Apr. 6, 2001	POD for ocean surface studies	4017

converted to mission status

BEACON EXPLORER-C

Beacon-C (BE-C) was launched in 1965 as part of the US National Geodetic Satellite Program. SLR tracking on BE-C was reactivated after many years to augment the current complex of satellites used to study the secular and long period tidal variations in the Earth's gravity field. Since all of the current geodetic satellites are orbiting at inclinations ranging from 50 to 110 degrees, BE-C satellite is the only useful target with a relatively low inclination (41 degrees).

A six-month campaign was initiated in July 1999. An extension was authorized through December 2001, and based on the success of this campaign, was voted by the ILRS Governing Board to be upgraded to an ILRS mission effective January 1st, 2002. Additional information can be found on the ILRS Web site at:

http://ilrs.gsfc.nasa.gov/satellite_missions/list_of_satellites/beaconC.html

GFO-1

The GEOSAT Follow-On 1 (GFO-1) program is the U.S. Navy's initiative to develop an operational family of radar altimeter satellites to maintain continuous ocean observation, including precise measurement of both mesoscale and basin-scale oceanography. GFO-1 was launched on February 10th, 1998 and ILRS tracking support commenced on April 22nd, 1998. With the failure of the on-board GPS units, SLR and Doppler are the only source of precise orbit data

GFO-1 was accepted by the U.S. Navy and was declared operational on November 29th, 2000. On April 5th, 2001, the ILRS Governing Board upgraded the GFO-1 satellite to ILRS mission status. Additional information for GFO-1 can be found on the ILRS Web site at:

http://ilrs.gsfc.nasa.gov/satellite_missions/list_of_satellites/gfo/index.html

NEW CAMPAIGNS

Three new tracking new campaigns were adopted by the ILRS 2001 (see Table 2.4-2).

Table 2.4-2. New ILRS Campaigns in 2001

Campaign	Initiated by	Start Date	Planned End Date	Purpose	No. Passes
Etalon 1 and 2	ILRS Analysis Working Group Ron Noomen	Apr. 1, 2001	Apr. 1, 2002	POD/ Improvement of the Earth Orientation Parameters (EOP)	3001
H2A/LRE	NASDA/Japan Hiroo Kunimori	Aug. 29, 2001	Sept. 29, 2001 Continued for interested stations	Test new launch vehicle for placing satellites in geosynchronous transfer orbit	18
Reflector	ROSAVIA-COSMOS Victor Shargorodsky	Dec. 10, 2001	Sept. 10, 2002	POD research for space debris detection	11

ETALON

Etalon are a Russian family (Etalon-1, Etalon-2) of passive geodetic satellites dedicated to satellite laser ranging. Etalon-1 was the first geodynamic satellite launched by the former Soviet Union. The Etalon spacecraft were launched in 1989 in conjunction with a pair of GLObal'naya Navigatisionnay Sputnikovaya Sistema (GLONASS) satellites. The mission objectives were to determine a high accuracy terrestrial reference frame and Earth rotation parameters, to improve the gravity field, and to improve the gravitational constant.

At the request of the ILRS Analysis Working Group, the ILRS Governing Board approved a six-month Etalon intensive tracking campaign from April 1st, 2001 to September 30th, 2001. The mission was subsequently through April 2002. The objectives of the campaign are to enhance Precision Orbit Determination (POD), station positions, EOP and EOP derivative determination, GM computation, and assessment of station biases (range and frequency bias).

Additional information can be found on the ILRS Web site at:

http://ilrs.gsfc.nasa.gov/satellite_missions/list_of_satellites/etalon/index.html

H2A/LRE

Laser Ranging Equipment (LRE) was a test of a SLR to help evaluate a new launch vehicle, H2A, in a transfer orbit for geosynchronous satellites. SLR tracking on LRE could also provide a means of calibrating SLR systems over a broad range of distances, help monitor vehicle spin rates, and support tests on the degradation of low-cost BK-7 cubes on the array. This mission, with its highly eccentric orbit, could also be used to refine current air drag and gravity field models.

The ILRS Governing Board approved a one-month campaign beginning at launch, August 29th, 2001. Due to a three-hour launch delay, good tracking conditions were lost for the first few months of the mission and no SLR data was achieved. Interested ILRS stations were encouraged to continue SLR efforts after the completion of the formal campaign and the Grasse LLR station acquired returns from the LRE satellite on December 17th, 2001. LRE support has continued on a limited basis.

Additional information can be found on the NASDA Web site at:

http://god.tksc.nasda.go.jp/lr/lre.html

And at the ILRS Web site at:

http://ilrs.gsfc.nasa.gov/satellite_missions/list_of_satellites/lre/index.html

REFLECTOR

The Reflector microsatellite (Figure 2.4-1) is a passive satellite with retroreflectors placed at reference points (nodes) about the spacecraft. The satellite was designed to use the SLR return signal structure for studies of spatial (angular) resolution, of spacecraft attitude, and identification of space debris.

The ROSAVIACOSMOS, Science Research Institute for Precision Instrument Engineering (IPIE) requested a nine-month campaign for the Reflector satellite, beginning immediately after separation from the METEOR-3M satellite. The ILRS Governing Board granted emergency approval of this campaign request shortly after launch in December of 2001. A formal request will be acted upon in early 2002.

Additional information can be found on the ILRS Web site at:

http://ilrs.gsfc.nasa.gov/satellite_missions/list_of_satellites/reflector/index.html

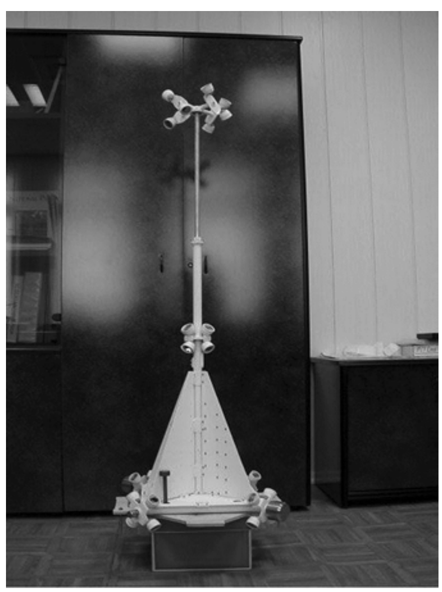


Figure 2.4-1. Reflector satellite.

UPCOMING MISSIONS AND CAMPAIGNS

Request for tracking support for new missions must be submitted to the Central Bureau, reviewed by the Missions Working Group and approved by the Governing Board. New missions request tracking support by first completing an on-line SLR Missions Support Request Form accessible through the ILRS Web site at:

http://ilrs.gsfc.nasa.gov/satellite_missions/ilrssup.html

2.5 NEW MISSIONS AND CAMPAIGNS PLANNED FOR 2002 — 2003

A number of new missions and campaigns are anticipated during 2002 — 2003 (See Table 1.3-1)

JASON-1

Jason-1 is an oceanography mission to monitor global ocean circulation, study the tie between the oceans and atmosphere, improve global climate predictions, and monitor events such as El Ni o conditions and ocean eddies. The Jason-1 satellite, a joint France/USA mission, is a follow-on to the TOPEX/Poseidon altimeter mission.

Although the Jason-1 satellite has onboard GPS receivers, the SLR data will provide a crucial centering of the orbit relative to the Earth's center of mass. SLR also provides the only absolute calibration of the radial orbit error through the analysis of high elevation SLR passes. Jason-1 was launched on December 7th, 2001 and will be maneuvered into a tandem orbit with TOPEX/Poseidon. The satellites will be separated by approximately one minute in time. SLR will commence on Jason-1 on January 14th, 2002 after the satellite is maneuvered into its final orbit. Several test passes have been taken by ILRS stations during this maneuvering period to ensure the retroreflector array performance.

Additional information can be found on the ILRS Web site at:

http://ilrs.gsfc.nasa.gov/satellite_missions/list_of_satellites/jason/index.html

ENVISAT-1

ENVIronmental SATellite (ENVISAT) -1 is the successor to the European Space Agency (ESA) Remote Sensing Satellites ERS-1 and ERS-2. It will provide continuity with most of the ERS-1, 2 altimeter and SAR measurements and adds significant new capabilities. The mission will: (1) provide long term data sets for both climatological and environmental research; (2) monitor and support studies of the Earth's environment and climate changes; (3) support management and monitoring of the Earth's resources, both renewable and non-renewable; (4) help the development of a better understanding of the structure and dynamics of the Earth's crust and interior.

SLR will be combined with DORIS for POD to calibrate the on-board altimeter. The altimeter data will be used to determine ocean surface heights to monitor global ocean circulation, regional ocean current systems, and study the marine gravity field.

ENVISAT-1 will be launched on March 1, 2002 and maneuvered into a tandem orbit with ERS-2. The satellites will be separated by approximately 30 minutes in time.

Additional information can be found on the ILRS Web site at:

http://ilrs.gsfc.nasa.gov/satellite_missions/list_of_satellites/envisat/index.html

GRACE

The Gravity Recovery And Climate Experiment (GRACE) is a joint US/German satellite mission, which will provide global high resolution estimates of the Earth's gravity field and its variability in time. The GRACE mission will have two identical spacecraft flying about 220 kilometers apart in a polar orbit 500 kilometers above the Earth.

GRACE will map the Earth's gravity fields by making accurate measurements of the distance and relative velocity between the two satellites, using GPS and a microwave ranging system. It will provide an efficient and cost-effective way to map the Earth's gravity fields with unprecedented accuracy. The results from this mission will yield crucial information about the distribution and flow of mass within the Earth and it's surroundings.

The SLR data will be used for precise orbit determination in combination with GPS tracking data for gravity field recovery, calibration of the on-board GPS Space Receiver, and technological experiments such as two-color ranging. The GRACE satellites will be launched on March 17, 2002 and will be separated by approximately 30 seconds in time.

Additional information can be found on the ILRS Web site at:

http://ilrs.gsfc.nasa.gov/satellite_missions/list_of_satellites/grace/index.html

ICESat (GLAS)

The Ice Cloud and land Elevation Satellite (ICESat) is scheduled for launch in December 2002, into a near polar Low Earth Orbit (LEO) at an altitude of 600 km with an inclination of 94 degrees.

ICESAT primary objectives are to study the mass balance between the polar ice sheets and global sea level change. Secondary objectives are to measure cloud heights and the vertical structure of clouds and aerosols in the atmosphere; to map the topography of land surfaces; and to measure roughness, reflectivity, vegetation heights, snow-cover, and sea-ice surface characteristics. The primary instrument onboard ICESAT is the Geoscience Laser Altimeter System (GLAS), an integral part of the NASA Earth Science Enterprise (ESE). GLAS will operate over ice, ocean and land.

SLR will be used for validation of GPS POD, back-up POD, and orbit maintenance.

For more information on ICESat refer to:

http://ilrs.gsfc.nasa.gov/satellite_missions/list_of_satellites/icesat/index.html

Gravity Probe B (GP-B)

Gravity Probe B will carry the Relativity Gyroscope Experiment being developed by NASA and Stanford University to test two extraordinary, unverified predictions of Einstein's general theory of relativity. The experiment will check, very precisely, tiny changes in the direction of spin of four gyroscopes contained in an Earth satellite orbiting at 400-mile altitude directly over the poles. The gyroscopes provide an almost perfect space-time reference system to measure how space and time are warped by the presence of the Earth, and how the Earth's rotation drags space-time around with it. These effects, though small for the Earth, have far-reaching implications for the nature of matter and the structure of the Universe.

SLR and GPS will be used for precision orbit determination. Launch is scheduled for 2003.

Additional information on Gravity Probe-B can be found at:

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

ADEOS-II

The ADvanced Earth Observing Satellite 2 (ADEOS-II) will support the monitoring of global environmental changes while continuing and furthering the broad-ranging observation technology created by ADEOS-1.

SLR data will be used to determine a precise orbit during the first 39 days of the mission. Once the Global Imager (GLI) instrument is turned on, SLR will cease operations due to the sensitivity of the sensor to 532 nm laser illumination. The ILRS will provide small tracking campaigns during the ADEOS-II lifetime as NASDA requires. SLR will provide limited amounts of data for the strengthening of the GPS solutions and validation/comparison of independently determined orbits.

Additional information on ADEOS-II can be found at:

http://ilrs.gsfc.nasa.gov/satellite_missions/list_of_satellites/adeos2/index.html

2.6 SCIENCE COORDINATOR REPORT

This coming decade has been referred to as the Decade of the Geopotential given the wealth of satellite mi s-sions ongoing and planned from year 2000 onward which are designed to improve our understanding of the Earth s geogravity and geomagnetic fields. For gravity field modeling, the CHAMP, GRACE, and GOCE missions are expected to yield many orders of magnitude improvement in field recovery. For geomagnetic studies, we again find CHAMP, along with _RSTED, SAC-C, DMSP-F15 and other mission planned for later in the decade. We see a wealth of radar altimeter missions including ENVISAT, JASON, TOPEX/Poseidon, ERS-2, and GFO that are currently on-orbit. Space-based laser altimetry will reach new levels of sophistication and science yield with the December 2002 launch of ICESat, and the eventual launch of VCL. Never before have we seen such an abundance of missions, with each being underpinned by space geodetic requirements to provide precise orbit determination, data validation, and model development and testing. For the geogravity and altimeter missions especially, cm-level orbit determination is the goal.

Geophysical change detection is a major area of scientific interest. Important signals, both in the geogravity and geomagnetic fields, and also in continental, ocean, and ice sheet topography will allow a direct assessment and monitoring of some of the most important dynamical processes ongoing within the Earth s environmental system.

At the same time it is important to recognize the ubiquity of the GPS Constellation for a wide range of space geodetic applications, and in support of most of these missions. And clearly SLR must be recognized and evaluated in light of the increasingly important role that GPS is playing in precision orbit determination and model recovery. Nevertheless, it is no accident that every altimeter and geogravity mission mentioned deploys a laser retroreflector array as part of its spaceborne complement. With regard to the importance of SLR, the designers of these missions have already spoken.

There are three major roles for SLR-based science support:

- Providing independent information, both as unambiguously accurate tracking data, and for model verification, to ascertain model performance and improvement when using GPS. This includes studying how SLR data matches orbits determined by GPS systems, evaluation of new geophysical models like static and time varying/tidal gravity models, and providing end-to-end system calibration support for altimeters.
- Supporting science investigations for which SLR is clearly the preferred data resource to achieve science goals.
- Providing a low cost, low risk, fail-safe source of back-up to other orbit tracking and monitoring systems. Herein, SLR has already salvaged two altimeter missions: ERS-1 and GFO

Science support deserves elucidation, for it is important not to loose sight of the critical role that SLR will play for the foreseeable future in supporting many pressing science objectives. Examples of these are discussed briefly below:

TIME VARYING GRAVITY FIELDS:

Monitoring the changes in the gravity field is a remote sensing of global changes in mass transport, complementary to other means of remote sensing. Temporal variations of the Earth s gravitational field can provide important global constraints to better understand models of mass movement and exchange ongoing within the solid Earth-hydrosphere-atmosphere system. These variations occur on a variety of time scales, and there is considerable variation in their character and amplitude since they are caused by variable, simultaneously occurring geophysical phenomena. Very accurate data acquired on highly stable orbits are required to resolve these effects. To date, SLR has uniquely supported recovery of the long wavelength components of the non-tidal, temporal variations in the gravity field and has provided unique insight into global scale mass-transport.

From the changes in secular orbital perturbations they induce, temporal changes in the zonal harmonics provide the largest and most readily observable effects. An evaluation of the SLR data acquired principally from Lagoes-1, Starlette, Ajisai and Lageos-2, has produced reliable estimates of the secular change in the J_2, J_3, J_4, J_5 and J_6 harmonics and quite remarkably, have shown sudden changes in the J_2 rate in recent years. It is the strength one sees from more than 25 years worth of tracking on the most stable orbits that gives SLR a unique advantage in revealing long term global-scale mass transport.

Aperiodic and seasonal changes in the complete low degree and order gravity harmonics have also been observed using SLR orbital analyses. Monthly (and for recent time periods, 10-day) time series have been produced and compared with predictions obtained from Atmospheric Circulation Model/General Circulation Model (ACM/GCM) have been shown considerable strength for the complete long wavelength gravity field.

LONG WAVELENGTH TIDAL MODELS:

The mechanical/elastic properties and internal structure of the Earth can be better understood by observing its response to external forcing over a wide range of frequencies. The rich tidal spectrum provides a range of forcing (from $2x10^{-5}$ to $1x10^{-9}$ Hz) which is highly complementary to that acquired from seismic sources (1 to $2x10^{-4}$ Hz). Tidal analyses have the capability of revealing a five-decade addition in frequency range of the observed Earth's response.

The small phase lag in the solid Earth's tidal response arises from anelasticity in its body. Isolating and observing this phase lag over a wide range of tidal frequencies is the goal. The most successful experimental approach is to orbitally analyze very precise SLR data, and from perturbed orbital motion, derive accurate tidal parameters representing the integrated mass redistribution in the Earth/ocean/atmospheric system. To date, SLR is the only technique which has produced accurate estimates of the "whole Earth" tidal response, with solutions available for the longest wavelength components of the main tidal frequencies. Forward models are then used to remove ocean and atmospheric contributions. Modeling the ocean tides, given their large rate of energy dissipation and complexity, has caused significant uncertainties for accurate forward modeling. However radar altimeter derived ocean tide models have made enormous advances recently and with these advances, recent efforts have produced reliable detection of the solid Earth's lagged response at several semi-diurnal and diurnal tidal frequencies. An important benefit of SLR over other methods is that, by observing long-period orbital perturbations, SLR allows the important degree-2 terms that describe the Earth's body-tide response to be isolated. No numerical quadrature of poorly spaced surface measurements is required; since a satellite's orbit naturally provides the best numerical quadrature algorithm.

Again, it is the length of SLR data time series on a multitude of satellites which has led to the effective separation and recovery of these tidal effects. Since the most important of these effects are in resonance with orbital motion, the semi-diurnal, diurnal and long period tides all manifest themselves with long period orbital perturbations. Therefore, many satellite inclinations, and many years of accurate data are required to achieve a decorrelated tidal series. Again, SLR has proven itself unique for this application.

With the long SLR tracking history on LAGEOS and Starlette, important results are starting to be seen for the solid Earth's response to the 18.6 and 9.3 year lunar tides. Problems arise in separating secular zonal geopotential effects from these very long period tides, and a very long data record is therefore required. Again, SLR uniquely provides this data resource. Studies of these long period tides are aimed at understanding the transition from the high-Q seismic regime to the low-Q glacial-rebound regime and to determine whether the transition is sharp or smooth. For example, it is important to verify that the Earth's response (Q) is significantly different for the 18.6 year tide from that observed at diurnal/semidiurnal frequencies.

From the analysis of tides, the energy dissipation in the solid Earth can constrain the anelastic properties of the Earth at frequencies much lower than those accessible with seismology. With the goal being the determination of Q as a function of frequency across the entire tidal spectrum, a significant challenge remains.

GEOCENTER AND STATION VERTICAL MOTIONS:

It is convenient to consider the motion of stations with respect to the Earth's center-of-mass as being composed of two parts: the translation of the polyhedron of crust-fixed stations with respect to the center-of-mass, and the deformation of the polyhedron. We refer to the translation of the polyhedron origin (ITRF origin) with respect to the center-of-mass as the geocenter motion. Accurate measurement of the geocenter motion is needed to supplement measurements of polar motion, Earth rotation, precession and nutation, which connect the terrestrial and inertial frames, and to complete the realization of the ITRF. The geocenter signal provides information about hemispherical mass redistribution in the atmosphere, oceans and surface water (ice-sheets, snow, soil moisture and ground-water) and is normally less than 10 mm at seasonal frequencies. Measurements of the geocenter motion with a few mm accuracy quantify the hemispherical mass transport in the Earth system and are useful constraints for understanding the processes that lead to the redistribution of mass on the planet. The tidally driven geocenter can be monitored to improve ocean tidal models. Herein, SLR continues to provide the most accurate system for the recovery of geocenter motion on a daily basis.

The radial component of the deformation of the station polyhedron is caused by the solid Earth's response to tidal and rotational potentials, to past and present loading of the crust by ice, water, and air, and by tectonic processes. Measurements of the vertical component of the deformation with few mm accuracy are useful in studying these effects, and are an essential part of the job of maintaining the accuracy of the terrestrial reference frame needed for full use of tide gauge and altimeter measurements of the ocean surface. While SLR continues to be important for determining the absolute vertical motion of sites located throughout the world, GPS is providing an increased capability to provide comparable measurements.

SUMMARY:

SLR tracking data will continue to make important contributions to the scientific results which will come from this decade of geopotential investigations. With the recent deployment of several new stations in the Southern Hemisphere and the implementation of more automation and systems improvements, global coverage has improved and the cost of SLR tracking has decreased, in some cases very significantly. The major challenge to further strengthen the SLR role is still largely a matter of cost and coverage. New highly automated systems under development offer promise of significantly improving both the economic and geographic limitiations with the current SLR network. With the effective development, testing, and deployment of these systems, a more geographically dense network, with lower operational costs, will yield SLR tracking coverage which far surpasses that available today.

Section 3

Working Group Reports

SECTION 3 - WORKING GROUP REPORTS

3.1 Missions Working Group

Hiroo Kunimori, *Communications Research Laboratories*
Scott Wetzel, *Honeywell Technology Solutions, Inc.*

INTRODUCTION

The Missions Working Group (MWG) was formed at the first ILRS meeting in Deggendorf, Germany in September 1998. Since then, the MWG has been interacting regularly is the execution of their duties to coordinate new and existing tracking campaigns and missions with the ILRS operations community. The MWG met formally twice in 2001, however the participation was limited in the Toulouse meeting due to the events of September 11, 2001. The first meeting was held in conjunction with the EGS meetings in Nice, France in March 2001 and the second during the SPIE meeting in Toulouse France in September 2001. Other than these meetings, the MWG has had many discussions either by phone or e-mail regarding a number of missions related topics. These topics included current or new missions and/or tracking campaigns, working with other ILRS working groups where the satellite, array or mission requirements impact other areas of analysis, engineering, network coordination, or other mission planning.

Several new missions were planned and launched during 2001 including Jason, Reflector, Meteor-3M, and three new GLONASS satellites.

Several tracking campaigns were proposed, planned and were executed during this period. They included the Etalon, LRE, and Reflector campaigns. STARSHINE-3 tracking also occurred on a temporary basis to determine the viability of SLR on such a low, quick-turnaround satellite.

Preparations are underway for the upcoming missions, GRACE A & B, ENVISAT-1, ICESat, and ADEOS-II scheduled to be launched in 2002.

CHARTER

A SLR system can only track one satellite at a time. There has been a steadily increase in the number of new satellites with different tracking requirements requesting SLR support. As this number has increased, the need has increased for an organized mechanism to review all requests for SLR support of future missions and campaigns and to ensure that the currently supported missions still require SLR tracking. The ILRS Missions Working Group is tasked to review the needs of current and future SLR missions and to make SLR tracking support and priority recommendations to the ILRS Central Bureau and Governing Board.

The Central Bureau refers Mission Support Request Forms submitted for new satellites to the MWG. The MWG reviews them for adequate scientific or engineering relevance and sufficient justification for laser tracking support. Additional requirements such as SLR temporal and spatial coverage, prediction services, data processing and community interest are reviewed. Special mission requirements such as time biases, drag functions, liberating functions, modes of calibration, accelerated data submissions, and organization of the data flow from the data centers to the mission analysis centers are reviewed for relevance and compliance with ILRS capabilities.

Whenever the normal procedures and formats are inadequate for proper support of a new mission, the MWG will tries work out possible solutions in cooperation with the Mission sponsor and the other Working Groups.

The MWG proposes to the ILRS Governing Board the acceptance or refusal of a new or modified mission, based on the documents submitted by the mission sponsor (including a mission plan and the current workload of the network).

The MWG recommendation to the ILRS Governing Board includes any changes in the current priority list required to accommodate the new missions

The full charter for the Missions working Group can be found at:

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

MISSIONS WORKING GROUP MEMBERSHIP

Table 3.1-1. Mission Working Group Members.

Name	E-Mail	GB Member	Position
Hiroo Kunimori	kuni@crl.go.jp	Yes	Coordinator
David Carter	dlcarter@pop900.gsfc.nasa.gov	Yes	Deputy Coordinator
John Degnan	jjd@ltpmail.gsfc.nasa.gov	Yes	GB Appointee
Wolfgang Schluter	schlueter@wettzell.ifag.de	Yes	WG Interface
Scott Wetzel	scott.wetzel@honeywell-tsi.com	No	
Pippo Bianco	bianco@asi.it	No	
Vladimir Vassilvev	lavaser@orc.ru	No	
Ulrich Schreiber	schreiber@wettzell.ifag.de	No	
Julie Horvath	julie.horvath@honeywell-tsi.com	No	
Paul Stevens	Paul.stevens@honeywell-tsi.com	No	

ACTIVITIES

Meetings

Two MWG working group meetings were held in 2001: the first was held in Nice, France during the EGS meetings in March 2001 and the second at the SPIE meeting in Toulouse, France in September 2001. The following sections describe the important issues of each meeting.

The Nice Meeting

Highlights of the Nice meeting include the approval for an Etalon tracking campaign to support Earth Orientation Parameters and to improve station bias identification and resolution. Other campaign news included the continuation of the BEC campaign through 2001 and the US Navy elevated the GFO-1 mission from a campaign to full mission status following acceptance of the satellite. Also, the mislabeling of satellites continued with the GLONASS-84 satellite. The MWG adopted the policy of not accepting a new satellite without receiving a state vector from the mission owner for proper identification.

The Toulouse Meeting

Due to the events in of September 11, 2001, there was no NASA representation at the MWG meeting. However, a meeting was held in Toulouse and was well represented and attended. Highlights of the meeting include a status of the Etalon and LRE campaigns, a status report on upcoming missions and a discussion on whether to bring full-rate data back as a deliverable to support atmospheric modeling for low altitude satellites and for signal processing analysis.

WORK IN PROGRESS

Continued efforts are required by the MWG to develop:

- A more automated and user friendly Mission Support Request Form
- A Mission Support Plan Template to help satellite hosts in mission planning. Efforts have been ongoing with the number of new launches that had occurred during 2001 to make mission planning activities smoother with the mission host.
- A procedure to periodically (1) review mission requirements and applicability of SLR to meeting these requirements and (2) require satellite owners or key science and technical contacts to justify continued SLR support

Issues such as SLR coverage and data volume will be reviewed; whole arc or pass segmentation may be planned to support a rapidly growing number of missions. Also considered is periodic intensive tracking campaigns to relieve the stress on the high priority missions.

UPCOMING MISSIONS

Table 1.3-1 summarizes the planned missions for 2002 and beyond

3.2 NETWORK AND ENGINEERING WORKING GROUP

Werner Gurtner, *Astronomical Institute at Berne*

MEMBER LIST

Table 3.2-1. Networks and Engineering Working Group Membership.

Name	E-Mail	GB Member	Responsibility
Werner Gurtner	werner.gurtner@aiub.unibe.ch	yes	Coordinator
Graham Appleby	gapp@mail.nerc-monkswood.ac.uk		
David Carter	dlcarter@pop900.gsfc.nasa.gov	yes	
John Degnan	jjd@ltpmail.gsfc.nasa.gov	yes	
Howard Donovan	howard.donovan@honeywell-tsi.com		
Van Husson	van.husson@honeywell-tsi.com		
Georg Kirchner	kirchner@flubpc04.tu-graz.ac.at		Deputy coord.
Rolf K nig	rolf.koenig@gfz-potsdam.de		
Hiroo Kunimori	kuni@crl.go.jp	yes	
John Luck	jmckluck@optusnet.com.au	yes	
Mike Pearlman	mpearlman@cfa.harvard.edu	yes	
Ulrich Schreiber	schreiber@wettzell.ifag.de		
Wolfgang Schl ter	schlueter@wettzell.ifag.de	yes	
Fumin Yang	yangfm@center.shao.ac.cn	yes	
Tom Zagwodzki	thomas.w.zagwodzki@gsfc.nasa.gov		

WORKING GROUP MEETINGS

In the year 2001 a working group meeting was held on March 27, 2001 in Nice, France during the XXVI General Assembly of the European Geophysical Society. The minutes of the working group meeting can be found on the ILRS web site at

http://ilrs.gsfc.nasa.gov/working_groups/networks_and_engineering/networks_activities

ACTIVITIES

Following the recommendations of the Working Group a new prediction mail exploder has been installed at CDDIS. It will allow for an easier backup. It will remove the necessity for all prediction providers to maintain their own distribution list and will help the stations to process the predictions automatically. Automated backup procedures at EDC have been defined, and will be invoked if the primary distribution system fails.

With a very few exceptions all station logs have been submitted. The station logs are screened for consistency, completeness, and format compliance by members of the Working Group. Van Husson is preparing summary spreadsheets for easy cross-comparison and evaluation of the log files.

The Working Group planned to hold a calibration follow-up meeting in Toulouse in late September 2001. The meeting had to be cancelled because of the serious travel restrictions after September 11. Some of the topics will be covered in a EUROLAS workshop to be held early 2002 in Herstmonceux.

Proposals for station qualification criteria were prepared by a small working group to be submitted to the Governing Board for approval.

3.3 Data Formats and Procedures Working Group

Wolfgang Seem ller, *Deutsches Geod tisches Forschungsinstitut (DGFI)*

3.3.1 Working Group

Member List

Table 3.3.1-1. Data Formats and Procedures Working Group Membership

Name	email	responsibility
John Luck	jmckluck@optusnet.com.au	Coordinator, retired
Wolfgang Seem ller	seemueller@dgfi.badw.de	Deputy Coordinator, Acting Coordinator
Ron Noomen	ron.noomen@deos.tudelft.nl	GB Appointee
Van Husson	van.husson@honeywell-tsi.com	CB Representative
Randall Ricklefs	rlr@astro.as.utexas.edu	
Graham Appleby	gapp@mail.nerc-monkswood.ac.uk	
Roger Wood	rw@slrb.rgo.ac.uk	
Roland Schmidt	rschmidt@gfz-potsdam.de	
Jan McGarry	Jan.McGarry@gsfc.nasa.gov	
Peter Shelus	pjs@astro.as.utexas.edu	LLR Representative
Werner Gurtner	werner.gurtner@aiub.unibe.ch	Leader, Prediction Formats SG (Lynx Team)
Stefan Riepl	riepl@wettzell.ifag.de	Network & Engineering WG Leader, Refraction SG (RSG)
Scott Wetzel	Scott.Wetzel@honeywell-tsi.com	CB Representative

Working Group Meetings

In 2001 only one Working Group meeting was held (the second planned meeting in autumn 2001 in Toulouse was cancelled) on Wednesday, April 24, in Nice, France.

Activities

A summary of activities is given at:

http://ilrs.gsfc.nasa.gov/ilrs/working_groups/dfpwg/data_activities.html

Most of the work was done in the Study Groups: the Prediction Formats of Randall Ricklefs and the Refraction Study Group of Stefan Riepl (see the following report).

3.3.2 Refraction Study Group (RSG)

Stefan Riepl, *Bundesamt f r Kartographie und Geod sie*

During the year 2001, the Refraction Study Group (RSG) continued to work on the remaining tasks to be solved according to the charter:

http: //www.wettzell.ifag.de/publ/rsg/charter.html

Member List

Table 3.3.2-1 Refraction Study Group Members.

Name	E-Mail
J.McK.Luck	JohnLuck@auslig.gov.au
P.Ciddor	Philip.Ciddor@tip.csiro.au
F.K.Brunner	brunner@aig.tu-graz.ac.at
R.Eanes	eanes@csr.utexas.edu
W.Gurtner	gurtner@ubeclu.unibe.ch
R.Haas	haas@oso.chalmers.se
J.Rueger	J.Rueger@unsw.edu.au
T.Otsubo	otsubo@crl.go.jp
P.J.Dunn	peter_j_dunn@raytheon.com
R.Govind	rameshgovind@auslig.gov.au
R.Noomen	ron.noomen@lr.tudelft.nl
T.Herring	tah@chandler.mit.edu
V.Mendes	vmendes@fc.ul.pt
H.J.Yan	yhj@center.shao.ac.cn
M.Becker	becker@ifag.de
S.Riepl	riepl@wettzell.ifag.de

V. Mendes (Mendes, V. B., G. Prates, E. C. Pavlis, D. E. Pavlis, and R. B. Langley "Improved Mapping Functions for Atmospheric Refraction Correction in SLR" *GRL*, 29 (10), 2002.) provided a mapping function as well as FORTRAN source code for the algorithm. So the RSG made significant progress with respect to providing an atmospheric refraction model at the millimeter accuracy level for the commonly used laser ranging wavelength 532nm. Other topics of interest focused on:

- an INTAS research grant for clarifying laser pulse propagation aspects for wavelengths affected by anomalous dispersion, (INTAS - International Association for the promotion of Cooperation with scientists from the New Independent States of the former Soviet Union.)
- evaluation of numerical weather prediction data to test the significance of horizontal gradients, and
- evaluation of two color laser ranging data in order to test mapping functions and/or zenith path delay models.

3.3.3. Prediction Format Study Group (LYNX Team)

Randy Ricklefs, *University of Texas at Austin*

Member List

Table 3.3.3-1. Prediction Format Study Group Members.

Name	E-Mail
Alain Journet	alain.journet@obs-azur.fr
Chris Moore	chris-moore@mail.com
Christopher Clarke	christopher.clarke@honeywell-tsi.com
Giuseppe Bianco	giuseppe.bianco@asi.it
Juergen Mueller	mueller@ife.uni-hannover.de
Roger Wood	rw@slrb.rgo.ac.uk
Ulrich Schreiber	schreiber@wettzell.ifag.de
Werner Gurtner	werner.gurtner@aiub.unibe.ch
Jan F. McGarry	jan.mcgarry@gsfc.nasa.gov
Julie E. Horvath	julie.horvath@honeywell-tsi.com
Randall L. Ricklefs	rlr@astro.as.utexas.edu
Richard J. Eanes	eanes@csr.utexas.edu

The study group was formed by the Data Formats and Procedures Working Group in Matera during the November 2000 meeting. The purpose was to create a consolidated format or formats for ranging predictions for all current and anticipated laser targets, including passive earth satellites, lunar reflectors, and transponders on or orbiting around the moon and other solar systems bodies or in transit.

During 2001, the group charter was finalized and a working document honed. The working document presented the current state of affairs for predictions in the SLR and LLR communities and tried to ask incisive questions as to the future of the process. As a result of ensuing email communications among study group members, several conclusions were reached:

- The predictions would be tabular in nature, so that an interpolator and not an integrator would generally be used;
- The elements of the predictions would be geocentric state vectors, possibly in the same reference frame as the existing IRV;
- Provision needed to be made for integrating or extrapolating past the end of the predictions for crew scheduling or in the event of an extended network communications failure;
- Geosynchronous satellites needed to be handled gracefully;
- New on-site and centralized prediction software would need to be developed; and
- Some type of file compression might be necessary due to the larger size of the prediction files.

SLR predictions would fit into the above specifications without difficulty. To identify any unique lunar prediction information to include, a feasibility study was begun, starting with modifications of existing lunar prediction code.

Not surprisingly, transponders present the largest source of uncertainty in terms of fields required in the format. Contacts were made in an effort to start solidifying the unique transponder requirements. Progress so far indicates a convergence on the format in the not-too-distant future.

3.4 Analysis Working Group

Ron Noomen, *Delft University of Technology*
Peter Shelus, *University of Texas at Austin*

Introduction

The most important aspect of the SLR/LLR observation is its absolute accuracy. This makes it a perfect technique to monitor or study elements of system Earth like geocenter (motion), absolute scale, global plate tectonics and vertical station deformations, or, in the case of LLR, fundamental lunar constants. This aspect has led to the reliance on SLR for the definition of origin (fully) and scale (together with VLBI) for IERS ITRF2000 model for global station coordinates and velocities. The SLR community also produces other (geo)physical products like Earth Orientation Parameters (EOPs), time-variations of the long-wavelength components of the Earth's gravity field, satellite orbit solutions and others.

Member List

Table 3.4-1. Analysis Working Group Members.

Name	E-Mail	GB Member
Graham Appleby,	gapp@mail.nerc-monkswood.ac.uk	GB Appointee
Richard Biancale	richard.biancale@cnes.fr	
Richard Eanes	eanes@csr.utexas.edu	
Ramesh Govind	rameshgovind@auslig.gov.au	
Van Husson,	van.husson@honeywell-tsi.com	CB Representative
Rolf Koenig	rolf.koenig@gfz-potsdam.de	
Hiroo Kunimori	kuni@crl.go.jp	
Cynzia Luceri	cinzia.luceri@asi.it	
Maria Mareyen	mamy@ifag.de	
Vladimir Mitrikas	geozup@cityline.ru	
Horst Mueller	horst.mueller@dgfi.badw.de	
Juergen Mueller	mueller@ife.uni-hannover.de	
Ron Noomen,	ron.noomen@deos.tudelft.nl	Coordinator
Konstantin Nurutdinov	konstantin.nurutdinov@ncl.ac.uk	
Toshi Otsubo	otsubo@crl.go.jp	
Erricos Pavlis	epavlis@helmert.gsfc.nasa.gov	
Bernd Richter	richter@ifag.de	
Remko Scharroo	remko.scharroo@deos.tudelft.nl	
Peter Shelus,	pjs@astro.as.utexas.edu	Deputy Coordinator, LLR Representative
Mark Torrence,	mtorrenc@geodesy2.gsfc.nasa.gov	CB Representative
Robert Weber		

The ILRS has been given the official status of Technique Center in the new organization of the IERS. As such, the ILRS is expected to produce a unique and official product on a number of the parameters mentioned above; as a first target a coordinated and unique EOP contribution to the weekly IERS Bulletins A is expected.

The AWG is dealing with issues like product quality control, development of (an) official ILRS product(s) and others. More detailed information, also on its membership list, can be found on the relevant web pages:

http://ilrs.gsfc.nasa.gov/working_groups/awg/index.html.

Activities in 2001

An important instrument for contacts and discussions among analysts proved to be the AWG workshops; in 2001, two were organized, notably in March (Nice, France) and in September (Toulouse, France).

Through the series of workshops, various issues have been debated and resolved. One of them is the product format. The AWG adopted the SINEX V1.0 format initially, but with time this turned out to have a number of shortcomings w.r.t. specific SLR analysis demands. Proposals for modifications are included in its official successor SINEX V2.0.

To develop various analysis issues, the AWG has initiated a number of so-called Pilot Projects, each with the goal to improve specific elements of SLR/LLR analysis results. The status and results of each of these will be discussed below.

A number of analysis institutes evaluate the SLR measurements on various satellites on a routine basis. The satellites include: ERS-2, ENVISAT, TOPEX/Poseidon, Jason-1, Stella, Starlette, Ajisaj, LAGEOS-1/2, GPS-35/36, and Etalon-1/2. The results are distributed in a rather uncoordinated way, i.e. each analysis center produces its own unique analysis report, which is made available to customers (stations, satellite managers) typically without comparison or checking with results obtained by others. The Pilot Project 1 *Unification of Fast-Turnaround Analysis Results* aims at the improvement of the interpretation of the "quality verdict" in the various analysis results, e.g. by looking at time-series of range and/or time biases, rather than at absolute values. Furthermore, it is the intention that all individual analysis results will be merged into a single report, with a unique assessment of the data problem(s) and its uncertainty. It is obvious that (differences in) station coordinates play a major role in the (dis)agreement of such QC results; consequently, all analysis groups involved are strongly encouraged to use ITRF2000.

The Pilot Project 2 *Computation of Station Positions and EOPs* deals with two of the fundamental analysis products of ILRS: station coordinates and EOPs. One of the goals is the development of a unique, best-possible (in terms of quality) analysis product which can be used by (specific elements of) the science community.

The project has seen a strong development with time. Initially, it dealt with a small (28 days) dataset of LAGEOS-1 observations only. At this moment, the participants work with SLR observations on LAGEOS-1 and -2, and also on Etalon-1 and -2. The project nicely illustrates the shift in emphasis, from procedures and formats to quality and contents. The Etalon spacecraft are expected to contribute to EOP products, global scale, station characterization, temporal variations in zonal terms of the gravity field and others. In Nice (March 2001), the AWG requested an intensive tracking campaign for the latter two spacecraft, initially for a duration of 6 months. The campaign has seen two extensions so far, and preliminary results have been reported at the AWG workshop in Nice (April 2002), whereas "final" results are expected to be presented at the next AWG workshop in Washington (October 2002). In spite of these efforts, the contribution of the Etalon satellites is limited in terms of data quantity (compared to LAGEOS); the preliminary analyses have shown quite varied contributions to analysis products.

Another aspect which has been resolved is the question on UT versus LOD. After many and lengthy discussions, the analysts have come to the consensus that the UT parameter is by definition indistinguishable from the (absolute orientation of the) ascending node of the satellite orbit, and therefor should be considered as a nuisance parameter. The estimation of LOD parameters is recognized as a useful analysis activity, however.

Although proposed and adopted by the AWG, the Pilot Project 3 *Orbits* has not really gained much momentum yet. The project will focus on a future analysis product, and is expected to stimulate improvement of the quality of solutions.

The Pilot Project 4 *Software Benchmarking* is aimed at quality control of the software in use at the various analysis centers. This pilot project deals with typical analysis results (orbits, parameters) obtained at different institutes, and strives for a thorough understanding of the differences. The goal of this project is to make sure that the various software packages in use at different analysis groups are free of errors

Outlook for 2002 and beyond

During the year 2002, significant developments of the various pilot projects can be expected. The results seen so far for the "harmonization" project are quite encouraging, and the "orbits" and "benchmarking" projects are in good starting positions. The progress of the "positioning + earth orientation" project is steady and significant.

3.5 Signal Processing *ad hoc* Working Group

Graham Appleby, *ITE Monks Wood*
Toshimichi Otsubo, *Communications Research Laboratory*

Member List

Table 3.5-1. Signal Processing ad hoc Working Group Membership.

Name	E-Mail	Responsibility
Graham Appleby,	gapp@mail.nerc-monkswood.ac.uk	Coordinator
Peter Dunn	peter_j_dunn@raytheon.com	
Georg Kirchner	kirchner@flubpc04.tu-graz.ac.at	
Reinhart Neubert	neub@gfz-potsdam.de	
Toshi Otsubo	otsubo@crl.go.jp	
Stefan Reipl	riepl@wettzell.ifag.de	
Ulrich Schreiber	schreiber@wettzell.ifag.de	Deputy coord.
Tom Zagwodzki	Thomas.W.Zagwodski@nasa.gov	

Overview of Progress During 2001

GLONASS

- We have acquired details of precise location and characteristics of each CCR, thanks to Missions WG;
- Attitude-dependent impulse functions have been computed for GLONASS and tested against single-photon range data;
- Demonstration that large (20-40mm) ambiguity exists in Center of Mass (CoM) correction for high-energy systems;
- Through the work of MWG, we now have an accurate geometry of the three types of LRA on the GLONASS satellites and have concluded that:
- The apparent mean radial bias in the GLONASS microwave-derived orbits was caused by a combination of incorrect information on the location of LRA plus the 'large array' effect;
- Details of the GLONASS arrays are now on the ILRS website.

GPS

The radial bias (~50mm) of the GPS microwave-derived orbits persists - we should re-visit the current understanding of the locations of the GPS LRAs.

LAGEOS, Etalon and Ajisai

We know the precise location and characteristics of each CCR.

Impulse response functions have been computed, where the reflection intensity is modeled as a function of effective reflection area, CCR reflectivity and diffraction effects. (Figure 3.5-1.)

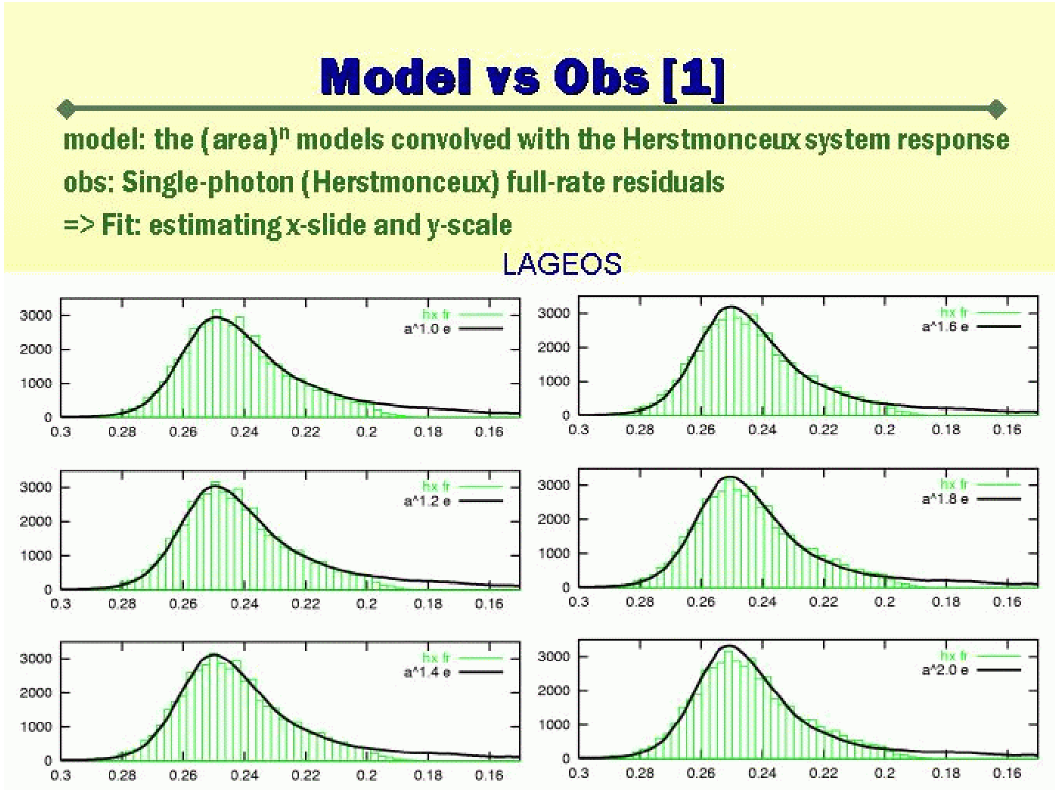


Figure 3.5-1. Calculated CCR Response.

Tested against single-photon range data; crucial to this stage is understanding the particular power law applicable to each satellite. The fit of the models to Herstmonceux single photon data can be used as a powerful indicator of this, as shown in the results for LAGEOS over a range of power-law models.

Further

We have demonstrated that the use of system-dependent CoM values is crucial for mm-level accuracy (e.g. the use of CSPAD at single- and multi-photon levels can influence appropriate CoM corrections by up to 5mm);

Discussions are underway with Honeywell colleagues on details of the NASA systems' CFD/MCP combinations, with a view to deriving appropriate CoM values for this important group of systems.

We plan soon to provide estimates of CoM values, or ranges of values, for the broad classes of systems (single-photon, multi-photon with C-SPAD, multi-photon with MCP/CFD) for LAGEOS, Ajisai and Etalon.

SECTION 4

NETWORK REPORTS

SECTION 4 - NETWORK REPORTS

4.0 INTRODUCTION

The ILRS Global Laser Ranging Network is made up of three regional networks:

- European Laser Network (EUROLAS) encompassing the European stations;
- NASA Network encompassing North America, and some stations in South America, South Africa and the Pacific
- Western Pacific Laser Tracking Network (WPLTN) encompassing Japan, China, Eastern Russia and Australia

and the Lunar Laser Ranging Network.

4.1 EUROLAS REPORT

Werner Gurtner, *EUROLAS*

Most of the organizational activities for the EUROLAS Network have now been subsumed under the ILRS Central Bureau and the various ILRS working groups. The routine long- and short-arc evaluations of passes performed by the NERC group have been extended to some non-EUROLAS stations. The near-realtime status exchange between now involving six of the EUROLAS stations continues to be useful for the operators, especially during the tracking of low satellites.

BOROWEIC

Stanislaw Schillak, *Space Research Centre, Polish Academy of Sciences*

The SLR Borowiec station operated continuously during the year 2001 without major failures. The station achieved returns during nighttime from 16 satellites under the framework of ILRS tracking program. SLR Borowiec tracked 709 passes during the year, producing about 11,000 normal points; the number of passes was strongly limited by weather conditions (75% clouds) and nighttime operations only. The accuracy of the system remains on a level similar to 2000, with a normal point precision of 8 mm and a long-term stability of 13 mm (according to the ILRS Performance Card). The main improvement in the system was the installation of a new cesium frequency standard HP-5071A as main station clock in December 2001. On-site orbital analysis of SLR data using the NASA GEODYN-II program was performed throughout the year. In addition to the SLR system operation, the Borowiec site is a permanent IGS station (BOR1), operating a Turbo ROGUE SNR 8000 receiver and IGLOS station (BORG) using a continuously operating 3S Navigation GPS/GLONASS receiver. Twice a year absolute gravimetric measurements are made at the site.

Figure 4.1-1. Borowiec SLR System, and the Boroweic staff (left to right): Jacek Bartoszak, Tomasz Celka, Danuta Schillak, Stanislaw Schillak, Stanislaw Zapasnik

Key Point of Contact

Stanislaw Schillak
Space Research Centre of the Polish Academy of Sciences
Astrogeodynamic Observatory
Borowiec
ul. Drapalka 4
62-035 Kornik
POLAND

Voice: +48-61-8170-187
Fax: +48-61-8170-219
Email: sch@cbk.poznan.pl

CAGLIARI

Aldo Banni, *Astronomical Observatory of Cagliari*

Laser station upgrades were underway through June 2001: the telescope (optics, motors, encoders, electronics, control/management hardware and software); the operations console (migration to Linux OS); devices (echo timing, signal processing). The station upgrade process continues.

Figure 4.1-2. Ranging from the Cagliari SLR site.

Satellite observations were made from June 30 through the end of 2001. The observations began as soon as the equipment was available. Unfortunately there were several interruptions in the tracking, and a low level of operations.

Table 4.1-1. Cagliari operations.

Total number of observation nights	70
Successful nights	36
Failed for meteorological problems	18
Failed for technical reasons	16
Low Earth Orbit Satellite observations	98
LAGEOS1-2 observations	8
RMS L.E.O. (cm)	5.8
RMS H.E.O. (cm)	3.9
L.E.O. Single shot precision (cm)	5.5
H.E.O. Single shot precision (cm)	3.8

Key Point of Contact

Aldo Banni
Astronomical Station of Cagliari
Loc. Poggio dei Pini
09012 Capoterra
ITALY

Voice: +39 070 71180 226
Fax: +39 070 71180 222
Email: banni@ca.astro.it

GRASSE PERMANENT AND ULTRA MOBILE STATION (FTLRS)

Francis Pierron, *CERGA*

During 2001 we continued to observe all LEO's and LAGEOS satellites with the permanent SLR system acquiring about 4400 passes with very good stability. The LLR system tracked LAGEOS, GLONASS and GPS passes simultaneously with lunar ranging.

We also completed a major technical upgrade of our Ultra Mobile Station in order to be able to very accurately calibrate the Jason satellite which was launched in December 2001 and tracked by FTLRS some days later.

Many technical points have been addressed in order to have both better accuracy and higher sensitivity to track LAGEOS. The FTLRS engineering work was completed at the end of summer 2001 and a qualification collocation campaign was conducted on different satellites including LAGEOS from September to December 2001 with the mobile system and the two others fixed stations (7835 and 7845) at the Grasse Observatory.

FTLRS collocation results

- 186 passes in three months on LAGEOS and all LEO satellites
- 52 LAGEOS passes including 41 simultaneous with the three systems
- 120 LEOS passes simultaneous with the fixed SLR station
- Validation of FTLRS performances at the level of few mm
- Bias SLR (7835) – FTLRS(7846) : 5 ± 1 mm
- Comparison with European stations on common passes

  FTLRS - Graz : 3 ± 1 mm

  FTLRS - Herstmonceux : -3 ± 1 mm

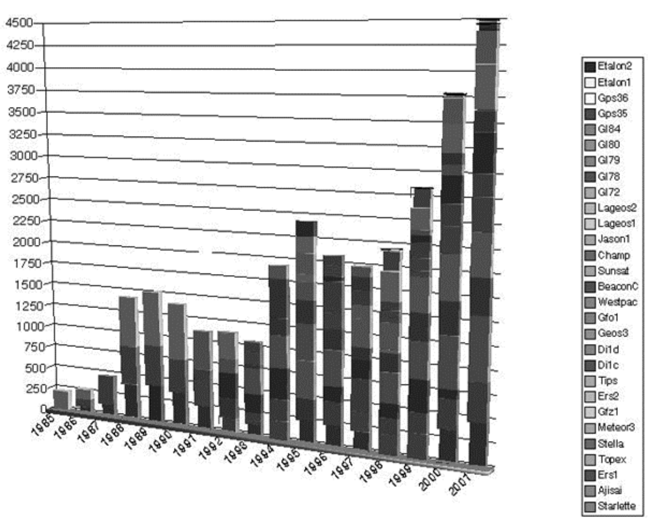


Figure 4.1-3. Passes acquired by the fixed SLR Systems, and the FTLRS System at Grasse.

The FTLRS system was packed for shipping at the end of December 2001 and moved it to Corsica Island (250 km south of Grasse in Mediterranean) on January 9, 2002. We deployed FTLRS at this site and acquired the first pass three days later and began the Jason1/TOPEX calibration campaign.

Figure 4.1-4. The Grasse Site.

Key Point of Contact

Francis Pierron
Observatoire de la côte d'Azur, CNES/GRGS
Avenue N. Copernic
06130 Grasse
FRANCE

Voice: 33 493405420
Fax: 33 493092614
Email: francis.pierron@obs-azur.fr

GRAZ

Georg Kirchner, Franz Koidl, *Austrian Academy of Sciences*

Range Gate Generator

In the summer of 2001, we began the design of a new range gate generator. The design was implemented in late autumn and winter by Martin Steindl, a diploma student from Deggendorf, Germany. Almost all of the hardware development was completed for the FPGA (Field Programmable Gate Arrays), resulting in the following specifications:

- requires external 1 pps, and 10 MHz frequency source;
- epoch based Range Gate pulses with < 500 ps resolution, and < 1 ns accuracy;
- laser repetition rates of up to some kHz;
- fully programmable via any standard 16-bit interface;
- complete epoch timing operation to ANY satellite, using the 10-Hz laser, or any future kHz laser system.

The hardware is finished, software implementation into our standard ranging programs is nearly completed.

Third Module for our Event Timer

For tests, for MultiColor measurements, and also for use as a spare part, we implemented a third Event Timer module (in addition to one start and one stop module) at the end of last year. One of the tests scheduled is to use the new module to measure the delay between compensated and uncompensated C-SPAD output, giving a measure of the return signal strength.

Ranging Software

The mount control has been changed completely in order to optimize pass switching between satellites, as we use that quite extensively. The mount now always takes the shortest path directly to the azimuth of next satellite. The mount also optimizes slewing between tandem satellites, like TOPEX – Jason1 and GRACE-A – GRACE-B, resulting in very short pass switching times, usually taking about ten seconds. That scenario allows more frequent pass switching, and gives more uniform distribution of normal points.

In the spring 2001 we finally joined the Real Time Time Bias Exchange Club, which is not only a very efficient tool for successful hunting of difficult LEO´s like Champ, but also proved to be an excellent motivation item for our observers – to get the highest score.

Operation

The year 2001 was the most successful year up to now for SLR Graz; for the first time, we acquired more than 5000 passes. To our surprise, this resulted in the highest number of NPs of all SLR stations, according to the ILRS Performance Report Card (slightly more than 100,000 NPs). The main disadvantage: We had to spend a lot of our capacity to keep the station running: more or less frequent repairs of dome mechanics, laser heads, laser power electronics, etc. Visit the Graz Web site at: http://www.iwf.oeaw.ac.at

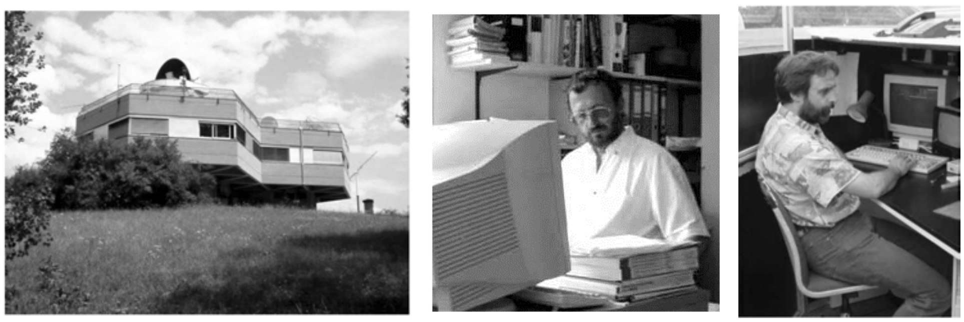


Figure 4.1-5. The Graz SLR Site and staff: Georg Kirchner and Franz Koidl

Key Point of Contact

Dr. Georg Kirchner
Space Research Institute
Department Satellite Geodesy, Austrian Academy of Sciences
Lustbuehelstrasse 46
A-8042 Graz
AUSTRIA

Voice: ++43-316-873-4651
Fax: ++43-316-873-4641
Email: kirchner@flubpc04.tu-graz.ac.at
Web: http://www.iwf.oeaw.ac.at

HELWAN

Magdy El-Saftawy, *National Research Institute of Astronomy and Geophysics (NRIAG)*

The observations from the Helwan SLR station are one of the most important in the SLR network because Helwan is one of two stations in Africa. The station was operated only by the Czech group (Czech Technical University of Prague) three months per year until 1997. During that period the Czech group was responsible for supplying the station by the spare parts and technical supports. During the 11th. International Workshop on laser Ranging (Deggendorf, Germany-1998) Prof. Dr. M. Tawadros announced that the Egyptian group is able to operate the station 12 months per year. During 1998 the station was operated by the Egyptian team with technical help from the Czech team. In 1999, 1391 observed passes were observed.

Figure 4.1-6. At the Helwan Station: the laser, mount, meterological sensors, a data analysis screen shot.

Figure 4.1-7. The Staff of the Helwan SLR station. From right to left: "Sami Fath-allah., Dr. Magdy El-Saftawy, Dr. Eng. Makram Ibrahim, Dr. Yousry Hanna,Mohamed Yehya, Dr. Khalil Ibrahim and Eng. Abd El-Rahman Ahmed.".

In 2000, Helwan observed only 426 passes and in 2001 there were approximately 140 passes observed because there was very little support for the station and the staff, as well as a shortage in spare parts.

Key Point of Contact

Dr. Magdy I. El-Saftawy　Voice: 00202 5549783
National Research Institute of Astronomy & Geophysics (NRIAG)
Helwan – Cairo　Fax: 00202 5548020
EGYPT　Email: nriag@frcu.eun.eg

HERSTMONCEUX, THE NERC SPACE GEODESY FACILITY

Philip Gibbs, *NERC Space Geodesy Facility,* Graham Appleby, *ITE Monks Wood*

Shown in the photograph of the Herstmonceux station is the (7840) SLR tracking telescope, the dome housing the safety radar and the tower supporting the HERS IGS Z12 antenna and meteorological sensors. The antenna of the HERP Z18 IGLOS station is behind the radar dome and not visible in this picture. This photograph, containing hot links to several elements of the Facility, is at:

http://nercslr.nmt.ac.uk/sgf_site/site_map.htm

Figure 4.1-8. The Herstmonceux site.

Satellite Tracking

During 2001, Herstmonceux observed all the satellites on the ILRS list.

EUROLAS Workshop

We are in the early stages of planning a Workshop at Herstmonceux for the EUROLAS stations aimed at eliminating errors over the network. Stations will be invited to bring their SR timers to the workshop for intercomparisons.

Timer Calibration

In our continuing quest to understand and quantify the range-dependent errors in our SR timers, we purchased two HP5370b interval timers and repeated all the tests we had previously made with the PPET (those results were presented at the SPIE meeting in Florence in 1999). The results from the HP tests agreed with the previous PPET tests. As we now have the means to continually monitor the behaviour of our SR timers, and it appears from the results that the PPET and HP have no range dependant errors, we made the decision that from an early date in 2002 we would use the results to remove from all our observations this range-dependent error which can reach a magnitude of about 8mm at the distance of LAGEOS. Details, including a table for correcting historical Herstmonceux data, were subsequently given in SLRMail 0891. We have also made a moveable target and plan to investigate the detailed behaviour of our SR timers at calibration distances.

Radar Drive System

A complete, new servo control system and drive motors for the safety radar have been installed and is being commissioned. The new system will be directly controllable from software.

Key Point of Contact

Dr Roger Wood, Philip Gibbs, David Benham, Robert Sherwood, Vicky Smith, Christopher Potter

NERC Space Geodesy Facility	Voice: +44 (0)1323 833888
Herstmonceux Castle	Fax: +44 (0)1323 833929
Hailsham	Email: slr@slrb.rgo.ac.uk
East Sussex BN27 1RN	Web: http://nercslr.nmt.ac.uk/
UNITED KINGDOM	

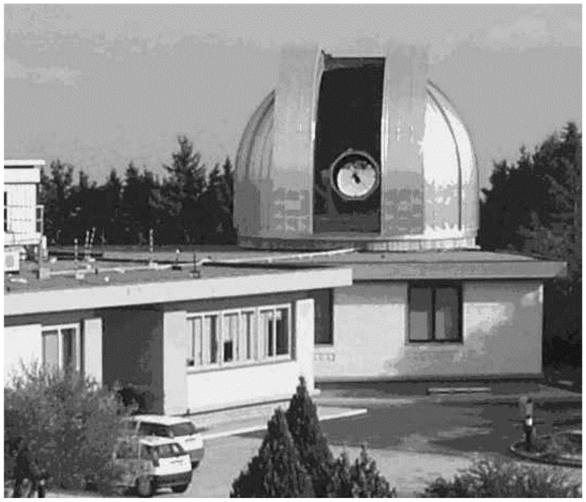
Matera

Giuseppe Bianco, *Agenzia Spaziale Italiana, Centro di Geodesia Spaziale "Giuseppe Colombo"*

During year 2001 the new MLRO (*Matera Laser Ranging Observatory*) has undergone extensive operational and debugging activities in preparation for the Acceptance Reviews foreseen for the first half of 2002. The system has performed quite satisfactorily and has been reported as the most precise SLR station in the ILRS network since when the first data were released, as illustrated in the following graph taken from the ILRS Web site:

http://ilrs.gsfc.nasa.gov/stations/performance_statistics/perf_2002q1.html

One of the most interesting activities has been the continuous monitoring of the LAGEOS-2 rotation rate by spectral analysis of full rate SLR orbital residuals observed by the MLRO.



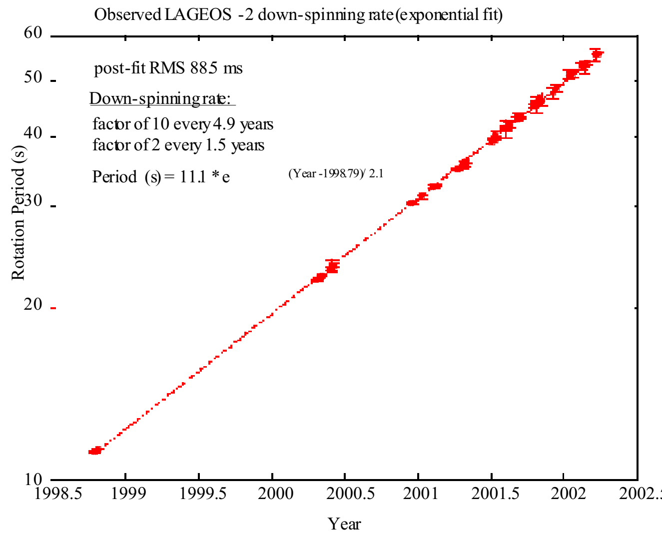


Figure 4.1-9. The MLRO Station, and LAGEOS-2 Spin Rate from MLRO Data.

Key Point of Contact

Giuseppe Bianco
Agenzia Spaziale Italiana
P.O. Box 11
75100 Matera
ITALY

Voice: ++39-0835-377209 (Institute)
Fax: ++39-0835-339005
Email: bianco@asi.it

METSAHOVI

Matti Paunonen, *Finnish Geodetic Institute*

Metsahovi (7806) was operational for the whole year. Some development work was devoted to comparisons of a new MOTIC multistop counter from Riga, HP 5370B and the old COMTIS currently in use. Comparisons of some AWG monthly coordinate solutions were continued, to improve the determination of the station position and possible range biases. Daylight capability was confirmed, but regular operation may need improvements in tracking and spectral filtering.

Key Point of Contact

Matti Paunonen
Finnish Geodetic Institute
Geodeetinrinne 2
FIN-02430 Masala
FINLAND

Voice: +358 9 2564994
Fax: +358 9 2564995
Email: geodeet@csc.fi

POTDSAM

Ludwig Grunwald, *GeoForschungsZentrum Potsdam*

In 2001, the currently operating Potsdam SLR station continued to support mainly LEO missions with special emphasis on CHAMP (the station tracked 135 passes of this satellite in 2001 under both day and nighttime conditions). Comparisons of the ranging electronics performance versus a Portable Pico Event Timer (P-PET) from Czech Technical University were done in September using three different SR620 time interval counters. Results of these comparisons with respect to counter linearity and stability were reported by Ivan Prochazka (CTU Prague) in the Toulouse Conference on Laser Radar Techniques in September.

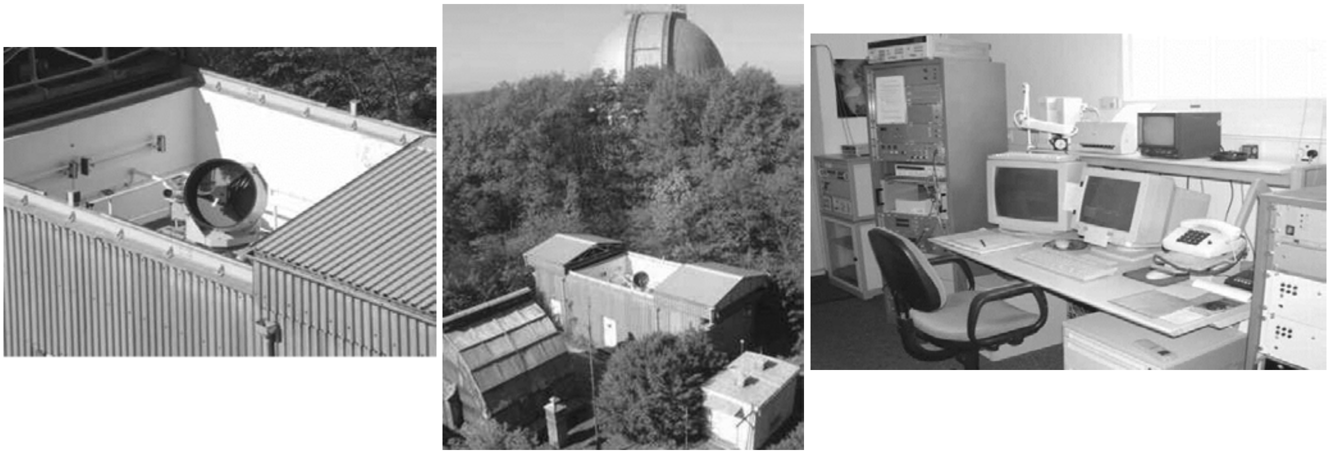


Figure 4.1-10. Potsdam SLR Station: telescope mount, facility, operations room.

The new SLR system (consisting of separate transmit and receive telescopes) performed the first successful satellite ranging experiments in July/August 2001. The tests continued through the following months and demonstrated that the anticipated ranging performance will be met. Routine SLR operations of the new system are expected to begin in summer 2002 after a period of collocation measurements with the present operating station.

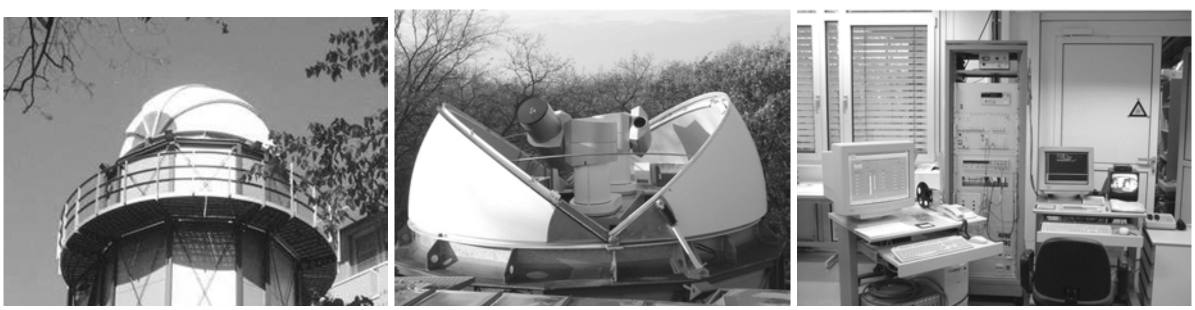


Figure 4.1-11. The new Potsdam SLR Station: facility, telescope mount operations room.

Key Point of Contact

Harald Fischer	Voice:	+49/331/288-1152
GeoForschungsZentrum Potsdam	Voice:	+49/331/288-1156 (SLR station)
Telegrafenberg	Fax:	+49/331/288-1759v
D-14473 Potsdam	Email:	fisch@gfz-potsdam.de
GERMANY		

SAN FERNANDO

Jorge Garate, *Real Institutory Observatorio de la Armada, San Fernando*

A complete review of the San Fernando SLR system was performed in the beginning of June with the invaluable collaboration and advise of Jean Gaignebet, Jean Louis Hatat and Jean F. Oneto from the Cote d'Azur Observatory. Following this review, a C-SPAD was implemented as a new detector for satellite tracking during nightime, while the XP2233B PM is still used for daylight tracking. On June 25th the first successful observation using the C-SPAD was made. As a result, the observation rms for the LAGEOS satellites were dramatically reduced both in single shot (from 55 mm at the end of 2001 second quarter to 18 mm at the end of the year) and in normal point (from 12 mm at the end of 2001 second quarter to five mm at the end of the year).

Figure 4.1-12. San Fernando SLR System at night.

Unfortunately, major damage to the HP5370A interval counter put the system out of operation from the end of July to the beginning of September. The Graz SLR station supported us by providing an SR620i counter which allowed resumption of operations in September, while we were awaiting the new SR620i. We received the new SR620i at the beginning of October and we kept both counters working together until the end of the year to validate operations.

Key Point of Contact

Jorge Garate
Real Instituto y Observatorio de la Armada
Cecilio Pujazon sn
11110 San Fernando. Cadiz
SPAIN

Voice: ++34 956 59 93 67
Voice: ++34 956 59 90 00 ext. 6595
Fax: ++34 956 59 93 66
Email: jgarate@roa.es

TRANSPORTABLE INTEGRATED GEODETIC OBSERVATORY (TIGO)

Stefan Riepl, Hayo Hase, Armin Boer, *Bundesamt fur Kartographie und Geodoesie*

During the year 2001 the Transportable Integrated Geodetic Observatory (TIGO), including the SLR module, was in standby mode awaiting shipment to Concepcion, Chile. The negotiations over the previous years led finally to a diplomatic note exchange aiming at the joint operation of TIGO in Concepcion. Apart from the BKG the Chilean side formed a consortium to share expenses for infrastructure and man power, providing a means to host TIGO for at least three years. The Consortium consists of the following institutions:

- The Universidad de Concepcion,
- The Universidad Catolica de la Santisima Concepcion,
- The Universidad Bio Bio and
- The Instituto Geografico Militar.

As there were major upgrades affecting the control and timing system of the SLR module, TIGO was subject to a collocation with the WLRS. During this collocation the TIGO SLR module proved to be operational in two color mode and capable of ranging to GPS satellites at least with the infrared channel. Due to ongoing improvements of the infrared detector, only data from the blue channel (423.5nm) was taken to evaluate the measurement. The collocation results showed agreement of the satellite measurements with respect to the local survey at the millimeter level. Figure 4.1-13 shows a sample satellite pass measured by both systems simultaneously. Immediately following the collocation campaign in September, TIGO was prepared for shipment to Chile. Despite its transportable design, to ensure the integrity of the delicate instrumentation, all components were tightly packed individually and re-stowed in the containers. This two month effort payed off, as the shock recorders installed for transport monitoring indicated a peak acceleration of 13g during the loading procedure on the ocean vessel (Figure 4.1-14) and avoided any risk of damaging the equipment due to high humidity. In the meantime the construction of the platform was on its way completion as shown in figure 4.1-14. By the end of the year 2001 the foundations and electrical connections were ready to host the TIGO containers, which were scheduled to arrive in mid-January 2002.

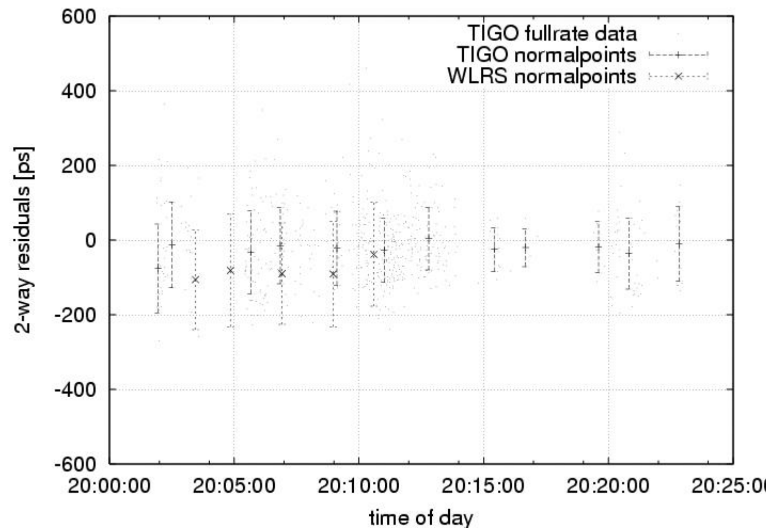


Figure 4.1-13: Sample satellite pass measured by the WLRS (532nm) and the TIGO SLR module (423.5nm). The points with error bars indicate the normal points, the dots represent the fullrate data of the TIGO SLR module.

Figure 4.1-14 (left): The TIGO six pack (six containers) during loading onto the ocean vessel; (right): The platform for hosting the TIGO containers in Concepcion under construction.

Key Point of Contact

Stefan Riepl
Observatorio TIGO
Universidad de Concepcion
CHILE

Voice: +56 41 207035
Email: riepl@wettzell.ifag.de

WLRS

Anja Schlicht, *Fundamentalstation, Wettzell*

In 2001, the WLRS telescope control unit was upgraded and re-integrated into the overall control software. The new control system was completed in April 2001, and again ready for laser ranging. Several more months are needed to debug the software and to adjust and improve the hardware (electronics and optics) in order to make use of the new picosecond event timer using 4 Dassault modules. During 2001, WLRS was in engineering status only.

The WLRS with its monoaxial telescope and the rotating miror as transmit-receive-switch could not measure very low-orbiting satellites, such as Champ. In 2001, a second small telescope with a Hamamatsu H 7422p-40 photomultiplier as a new detector was added to the primary telescope. The second receive path is coupled to the real time calibration facility via a set of mirrors reflecting a small part of the laser pulse into the second aperture. Figure 4.1-15 shows the small second telescope mounted on the primary 75cm telescope.

Figure 4.1-15. Second aperture at the WLRS to measure very low orbiting satellites.

Key Point of Contact

Anja Schlicht
Fundamentalstation Wettzell
Sackenriederstrasse 24
D-93444 Koetzting
GERMANY

Voice: 09941/603201
Fax: 09941/603222
Email: schlicht@wettzell.ifag.de
Email: laser@wettzell.ifag.de (station)

ZIMMERWALD

Werner Gurtner, *Astronomical Institute, University of Berne*

http://www.aiub.unibe.ch/zimmoper.html

Dielectric Coating

Early 2001 the three smaller mirrors of our telescope (i.e., M2 and M2 and the deflection mirror DM used by the tracking and CCD cameras) were recoated with broad-band dielectric coating. The previous protected silver coatings did not age favorably under the rather harsh atmospheric conditions. The new coatings show a very good reflectivity for the laser wavelengths as well as in the full band used for the optical astronomy activities.

Ranging in the Infrared

Range tests with a SPAD in the primary wavelength of our Titanium-Sapphire laser (846 nm) showed an unacceptable high scatter of the ranges (Figure 4.1-16):

We will purchase one of the new infrared Hamamatsu photo multipliers and start doing tests in 2002.

Laser Pulse Width

The single-shot RMS of flat-target calibrations continued to be larger than expected. Stereak camera pulse-width observations performed by J. Gaignebet of the Grasse Observatory and his group revealed that the pulse width was much larger than the expected 100 ps FWHM. An change of the etalon in the laser restored the pulse width to the nominal value.

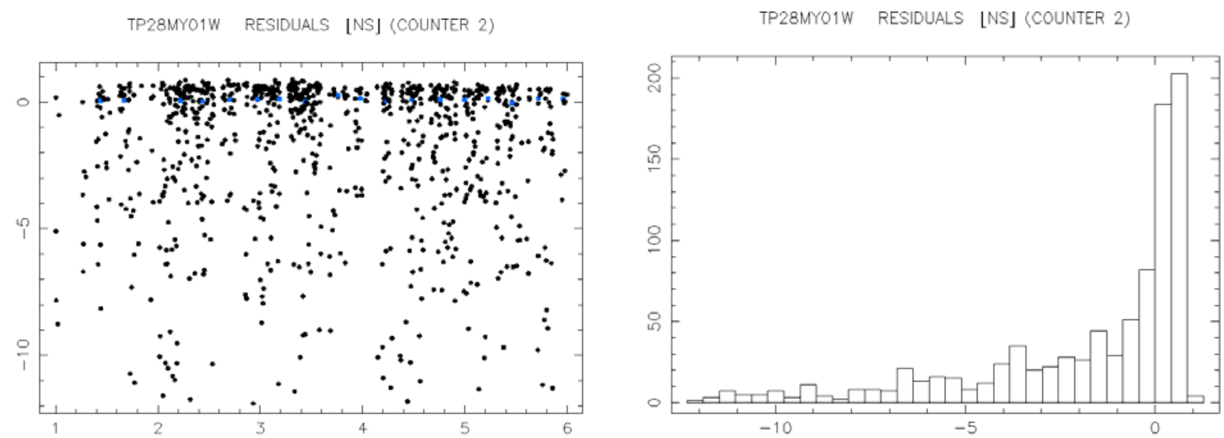


Figure 4.1-16. A. Residuals of a TOPEX Pass in Infrared. B.Histogram of the Residuals of a TOPEX Pass in Infrared

Station Computer

The two clustered VAX computers were replaced by one DEC Alpha system. The source code of the user programs only needed marginal modifications; however, all programs had to be recompiled.

Fully-Automated Operation

The tracking program was modified to allow it to run in batch (i.e., background) mode, too. A very few input variables only (power-up time, start time, stop time, "observer") have to be specified when the program is launched. All the rest, i.e., laser power up, initialization of the telescope, opening of the dome, definition of the observation scenario within the specified observation window, tracking and data collection, standby mode at the end, is performed automatically by the software. An observer can connect a special client program through TCP/IP with the tracking program for remote control of the batch process, if necessary. The automated operation is mainly used to bridge gaps between subsequent shifts or to extend shifts beyond the standard 8 to 9 hours.

Satellite Tracking

The year 2001 was the most productive year since the installation of the new system in 1995/1996, with more than 3,000 passes, 45,000 normal points and 40,000 minutes of successful tracking.

Key Point of Contact

Werner Gurtner	Voice:	++41-31-6318591 (Institute)
Astronomical Institute		++41-31-8190050 (Observatory)
University of Bern	Fax:	(+41)-31-631-3869
Sidlerstrasse 5	Email:	werner.gurtner@aiub.unibe.ch
CH-3012 Bern	Web:	http://www.aiub.unibe.ch/zimmoper.html
SWITZERLAND		

Figure 4.1-17. The Zimmerwald Station.

4.2 NASA NETWORK

David Carter, *NASA Goddard Space Flight Center,* Jack Stevens*, HTSI*

The NASA SLR Network during 2001 consisted of eight solely operated or partnered stations. Stations were located within North America, the West Coast of South America, the Pacific, Western Australia, and South Africa. NASA SLR operations are supported by Honeywell Technical Solutions, Inc. (HTSI), University of Hawaii, University of Texas, Universidad Nacional de San Agustin, Australian Surveying & Land Information Group, the National Research Foundation of South Africa and the University of French Polynesia/CNES.

MOBLAS-4

Jack Stevens*, HTSI*

MOBLAS-4 provided satellite laser ranging capability on a 24 hour, 7-day per week basis at the Monument Peak, California location. The MOBLAS-4 occupation at Monument Peak during 2001 represents its 18th year at this site.

The MOBLAS-4 system ranked among global leaders in all significant data quantity and quality performance categories in 2001. MOBLAS-4 was first among all global SLR systems in total LEO pass segments tracked, which totaled 4,586. MOBLAS-4 also ranked second among global systems in total number of pass segments tracked with 5,997.

The system and crew achieved 97% efficiency in the capture and production of high quality LAGEOS passes with an average single shot RMS of less than 9mm.

System upgrades to MOBLAS-4 during 2001 included the installation of the Laser Data Processing System containing the new Generic Normal Point Processing package v2.0.

Figure 4.2-1. MOBLAS-4 Station, Monument Peak, California.

Key Point of Contact

Gary Gebet
HTSI, NASA SLR Tracking Station
P.O. Box 130
Mt. Laguna, CA 92048-0130
USA

Voice: 619-473-9754
Fax: 619-473-8387
Email: m4mgr@slral2.honeywell-tsi.com

MOBLAS-5

Jack Stevens*, HTSI*

MOBLAS-5 provided satellite laser ranging capability on a 12 hour, 6 1/2-day per week basis at the Yarragadee, Australia location. The MOBLAS-5 occupation at Yarragadee during 2001 was it's 22nd year at this location.

MOBLAS-5 productivity and data quality was among SLR global leaders in all statistically relevant categories in 2001. The system and crew provided more satellite tracking coverage (over 100,000 ranging minutes) than any other SLR system in the world. MOBLAS-5 also ranked first among all global SLR system in total satellite pass segments tracked (over 6,300). SLR data yields included over 89,000 total NP captured while maintaining outstanding data quality standards.

The MOBLAS-5 system produced over a 98% high quality LAGEOS NP capture rate with an average single shot RMS of 9.8mm.

No major system configuration changes to MOBLAS-5 occurred during 2001.

Additional information for MOBLAS-5, a joint NASA/GSFC and the National Mapping Division of Australian, can be found in the following section.

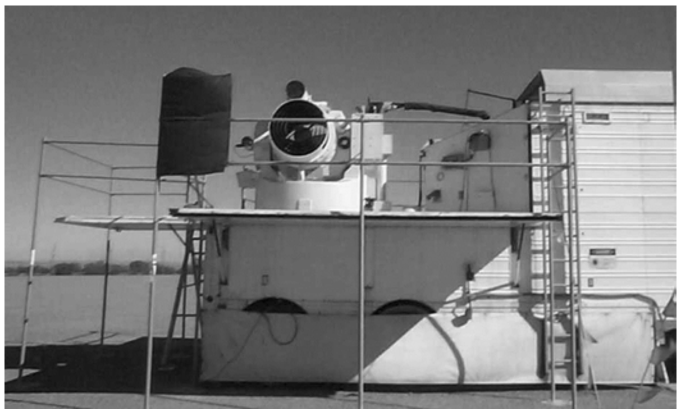


Figure 4.2-2. MOBLAS-5 Station, Yarragadee, Australia.

Key Point of Contact

P.O. Box 137
Dongara Western Australia 6525
AUSTRALIA

Voice +61 (0)8 99291011
Fax: +61 (0)8 99291060
Email: moblas@midwest.com.au

MOBLAS-6 AT HARTRAO

Ludwig Combrinck and Wilhelm Haupt, *Space Geodesy Programme, HartRAO*

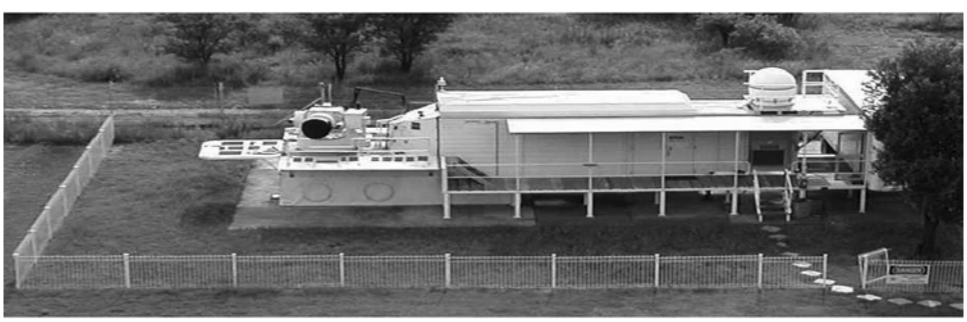


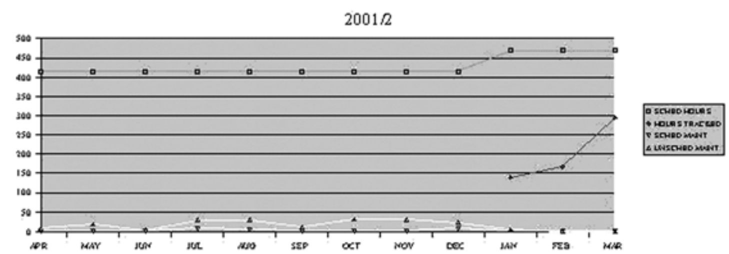
Figure 4.2-3. MOBLAS-6 at HartRAO.

During 2001 MOBLAS-6 continued to operate as part of the Hartebeesthoek Radio Astronomy Observatory (HartRAO) Space Geodesy Program in collaboration with NASA. High quality data are delivered consistently, MOBLAS-6 ranked first in the ILRS community for best LAGEOS NP RMS during 2001. The station proved to be reliable as no major repairs to instrumentation had to be carried out, although some older supporting peripherals (e.g. air conditioner) failed, adversely affecting tracking operations. Spares and other inventory items were captured into a database system to simplify maintenance.

The MOBLAS-6 system exceeded the global network standard of 1500 high quality satellite tracks, by tracking over 2,700 total satellite segments, and delivered over 27,000 normal points. Noteworthy accomplishments included above standard tracking of LEO satellites. Current tracking is maintained at 116 hours per week. This comprises two 8-hour shifts per day for three weeks and three 8-hour shifts per day for one week. Depending on future funding, it is envisaged that 24 hour per day tracking could be done on a routine basis.

Future activities will include a complete site survey to determine eccentricities between the SLR, VLBI, GPS and DORIS reference points in order to quantify discrepancies detected by previous site surveys.

Operational Hours vs Maintenance Hours



2001/2	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	TOTAL
SCHED HOURS	415	415	415	415	415	415	415	415	415	470	470	470	5145
HOURS TRACKED										139	167	295	601
SCHED MAINT	2	2	2	8	5	2	2	2	8	3	2	2	40
UNSCHED MAINT	8	20	4	30	30	12	33	32	24	6	1	0	200

Comments: Unscheduled Maint: Breakdowns, power failures etc.
Scheduled maintenance: preventative, routine checks, repairs during tracking or unsuitable weather conditions.

Figure 4.2-4. MOBLAS-6 Operational versus Maintenance Hours.

The plot of operational versus maintenance hours (Fig.4.2-4) indicates a reasonably high ratio of scheduled hours to unscheduled maintenance. Actual hours tracked has only been recorded after 2001.

Our winter months are more conducive to tracking and subsequent data output as summer months tend to have cloudy spells for several days or typically thunderstorms in the late afternoon. The MOBLAS-6 crew are integrated with the other space geodetic activities to allow a wider base of training and skills development.

Geodetic crew at HartRAO: Ludwig Combrinck (Programme Leader), Wilhelm Haupt (Station Manager), Louis Barendse, Johan Bernhardt, Marisa Nickola, Lesiba Ledwaba, William Moralo, Pieter Stronkhorst, Piet Mohlabeng, Conrad Mahlase.

Key Point of Contact

Dr. Ludwig Combrinck
Space Geodesy Programme
HartRAO
PO Box 443
Krugersdorp 1740
South Africa

Phone: +27 12 326 0742
Fax: +27 12 326 0756
E-Mail: ludwig@hartrao.ac.za
WWW: http://hartrao.ac.za

MOBLAS-7

Jack Stevens, *HTSI*

MOBLAS-7 provided satellite laser ranging capability on a 24 hour, 7-day per week basis at the Greenbelt, Maryland location. The year 2001 in Greenbelt was the 20th year MOBLAS-7 has been at this location.

In 2001, the MOBLAS-7 system was again among the global SLR system leaders in both SLR data productivity and data quality. Data volume increased from 2000 in all relevant statistical categories. MOBLAS-7 ranked 2nd among all global SLR systems in total satellite segments tracked with 6,242. In addition, 95,622 Normal Points were delivered to the scientific user community, representing the 2nd highest total data volume among all global SLR systems. MOBLAS-7 also produced 4,988,826 fullrate observations which was 3rd highest globally.

The system and crew achieved 98% efficiency in the capture and production of high quality LAGEOS with an average single shot RMS of 1cm.

Configuration changes at MOBLAS-7 during 2001 included the installation of the Generic Normal Point Processing System in February. In addition, the MOBLAS-7 Laser Cavity (Pulse Slicer) was upgraded in September 2001.

Figure 4.2-5. MOBLAS-7 at GGAO, Greenbelt, Maryland.

Key Point of Contact

Maceo Blount
HTSI
NASA SLR
515 Mission Dr
Lanham, MD 20706
USA

Voice: 301-286-5050
Fax: 301-286-1636
Email: maceo.blount@honeywell-tsi.com

MOBLAS-8

Keitapu Maamaatuaiahuta, *Tahiti Geodetic Observatory, maamaatu@upf.pf*

Due to many system breakdowns and important crew training sessions, tracking in 2001 was primarly done during the months of April and May.

Figure 4.2-6. MOBLAS-8 in Tahiti.

Major technical problems encountered at MOBLAS-8 were:

- MPACS failure in February 2001
- Burning of the slip rings around March 2001.
- MPACS failure in July 2002. Because some crewmembers were leaving, the MPACS was not fixed until new crewmembers joined in September 2001.
- Major changes in crewmembers at MOBLAS-8:

During the first half of the year, the crew was composed of Nicolas Blanchard (station Manager), Karl Daues (technician operator), Sebastien Deroussi (operator), and Katia Garceran(operator). Sebastien Deroussi left the team at the end of May. Karl Daues resigned by the end of June. Nicolas Blanchard left at the end of September.

Two new crewmembers, David Gavin and Yannick Vota, started in September.

The station manager has been Keitapu Maamaatuaiahutapu since July 2002.

By November 2001, tracking re-started at MOBLAS-8 with HTSI engineers as well as training of new crewmembers. The crewmembers are now: Keitapu Maamaatuaiahutapu (station manager), David Gavin (technician operator), Yannick Vota (technician operator), Katia Garceran (logistics). The Web site url is:

http://www.upf.pf/geos/laser.html

Key Point of Contact

Dr. Keitapu Maamaatuaiahutapu
Tahiti Geodetic Observatory
CUPF
BP 6570
98702 Faaa Aeroport
Tahiti
FRENCH POLYNESIA

Voice: (689)803.841
Fax: (689)803.842
Email: mamaatu@upf.pf

HOLLAS

Dan O'Gara, *LURE Project, University of Hawaii*

The Mount Haleakala Laser Station (HOLLAS) tracking operations were hindered in 2001 due to the failure of a sub-contractor to deliver an acceptable telescope controller. The telescope controller was the final piece of the system upgrade at HOLLAS, but the delivered device never met specifications. And, after months of negotiations, the sub-contractor went out of business. A replacement telescope controller was designed and constructed in 2001 using University of Hawaii engineers and technicians. This “in-house” developed controller was being installed at the observatory for testing at years end.

In June the Air Force Research Laboratory's prime contractor, Boeing Rocketdyne, installed at HOLLAS a real time connection to the FAA radar in Honolulu. However, the system does not have the capability to safely control the laser autonomously. It is being used at HOLLAS as a display only. A real time display is available both to the operator inside, and to the Laser Safety Officer (LSO) outside. Modifications to make the system safe for use as a replacement for the LSO have been discussed with the Boeing developers.

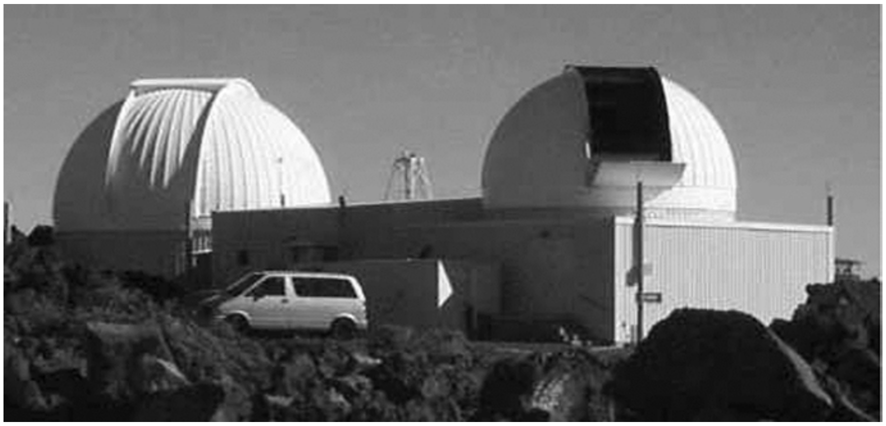


Figure 4.2-7. The HOLLAS Station Mount Haleakala, Hawaii .

Because of the development of the "in-house" telescope controller, HOLLAS was able to field only a single full time, 2 person satellite tracking shift during the year, using a telescope controller that has very poor tracking characteristics. Despite the technical problems, HOLLAS was able to contribute 16,525 Normal Points to the ILRS during 2001. Further, HOLLAS was ranked in the top third in three of the ranking categories used in the ILRS Global Performance report. (LAGEOS Single Shot RMS, LAGEOS Short Term Bias, and Data Delivery Latency).

HOLLAS Team Members: Dan O'Gara (Project Manager), Craig Foreman, William Lindsey, Jr., Timothy Georges, and Jacob Kamibayashi.

Key Point of Contact

Daniel J. O'Gara
LURE Project Manager
University of Hawaii
4761 Lower Kula Road
PO Box 209
Kula, HI 96790
USA

Voice: 808 876 7600 x.106 (Kula Office)
808 243 5895 x.2 (Observatory)
Fax 808 876 7603
Email: ogara@ifa.hawaii.edu

MCDONALD LASER RANGING STATION (MLRS)

Peter Shelus, *University of Texas*

The McDonald Observatory laser ranging station, MLRS, is located in the Davis Mountains of west Texas, near Fort Davis, Texas (USA). It continued its SLR/LLR activities as a part of the NASA laser ranging network during 2001. The principal source of funding is a contract from NASA Goddard Space Flight Center, Code Y. However, vital additional funding is provided by several grants from NASA Code S and the National Science Foundation. SLR data volume continued to be excellent during this report period and LLR data volume was somewhat improved over that obtained during 2000. Total data yield for the MLRS, including the Moon, were 3,534 passes (up from 3,174 passes), 37,498 normal points (up a bit from 37,057 normal points), and 34,384 minutes (up from 31,687 minutes) of tracking data.

All MLRS SLR/LLR data are available through the several data centers of the ILRS. These data are transmitted to the data centers in near-real-time, using standard SLR/LLR formats. Because of a continuing very tight financial situation, there have only been minimal upgrades and improvements at the MLRS. Activity continues to be directed toward keeping the station operational and in a data gathering mode.

Peter J. Shelus, Project Manager, continued his efforts on behalf of the ILRS, serving as associate director of the ILRS/AWG, member of the ILRS Directing Board, and lunar representative to the IERS. Mr. Randall L. Ricklefs, Software Manager, continued his efforts on behalf of the ILRS, serving as a member of the Data Formats Working Group and spear-heading the project for a more comprehensive data format to be used for SLR, LLR, and laser transponder data. Mr. Jerry R. Wiant continued as Project Engineer. Observers at the MLRS were Windell L. Williams, Kenny T. Harned, Martin L. Villarreal, and Anthony R. Garcia. Rachel M. Green served in the role as part-time Technical Assistant.

Figure 4.2-8. The MLRS Station at McDonald Observatory, Texas. Staff members(left to right): Martin Villarreal, "the mouser", and Jerry R. Wiant

Key Point of Contact

Peter Shelus
McDonald Observatory
Department of Astronomy
The University of Texas at Austin
Austin, TX 78712
USA

Voice: (512) 471-3339
Fax: (512) 471-6016
Email: pjs@astro.as.utexas.edu

TLRS-3, AREQUIPA

Jack Stevens, *HTSI*

TLRS-3 supplied SLR tracking from Arequipa, Peru for the 11th year at this location.

The TLRS-3 SLR tracking coverage increased slightly in 2001 logging 13,608 minutes (10,520 in 2000). TLRS-3 contributed over 27,000 NP to the scientific user community. Once again TLRS-3 provided outstanding tracking coverage of LEO satellites, collecting over 24,000 NP for these satellites during 2001. The system and crew achieved 99 % efficiency in the capture and production of high quality LAGEOS with an average single shot RMS of less than 8mm.

Figure 4.2-9. TLRS-3 at Arequipa, Peru.

Configuration changes at TLRS-3 during 2001 included the installation of the Generic Normal Point Processing System in May. In addition, the TLRS-3 received a True Time GPS steered rubidium and CNS clock.

Key Point of Contact

Victor Lucano
UNSA
Casilla Postal
2095 Arequipa
PERU

Voice: 051-054-448244
Fax: 051-054-448241
Email: t3mgr@unsa.edu.pe

TLRS-4

Jack Stevens, *HTSI*

TLRS-4 functioned as an engineering test bed in Greenbelt, Maryland in 2001

4.3 WESTERN PACIFIC LASER TRACKING NETWORK (WPLTN)

AUSTRALIAN STATIONS

Jim Steed, *Geodesy Section/Division of National Mapping, jimsteed@auslig.gov.au*

The Australian Surveying and Land Information Group (AUSLIG) was renamed National Mapping Division (NMD) after merger in October with the former Australian Geological Survey Organization (AGSO) to become the new entity Geoscience Australia. Throughout the year AUSLIG/NMD funded and oversaw the operation of both the MOBLAS 5 (Yarragadee) and the Mount Stromlo SLR stations, through contracts with BAE Systems and Electro Optic Systems respectively.

John Luck retired from active duty on 19 December 2001 after nearly 36 years monitoring Earth rotation by one means or another and keeping track of the country's time if not his own.

The activities of Geoscience Australia's Space Geodesy Analysis Center (SGAC) are described separately. Geodesy personnel played key roles in organizing SLR activities, and other space geodesy activities, for the Permanent Committee on GIS Infrastructure in the Asia-Pacific region (PCGIAP), especially through the latest of its series of annual campaigns "Asia-Pacific Regional Geodetic Project 2001" (APRGP'01) which have been conducted since 1997. Similarly, substantial contributions were made to the Asia-Pacific Space Geodynamics project (APSG).

YARRAGADEE

The station operated virtually unimpeded during 2001. It acquired 3850 LEO, 1172 LAGEOS-1 and -2, and 1380 high satellite passes, for a total of 6402 passes for the calendar year (the same as Mt. Stromlo last year!), comfortably ahead of second best for productivity. In fact, it ranked 1st of all stations in 6 of the 14 categories reported in the 4th Quarter 2001 ILRS Performance Report, and 2nd in another 3 categories. This was accomplished in spite of unusually heavy rainfall during much of the year.

MOBLAS-5 contributed notably in the post-launch intensive tracking campaigns on the new missions STARSHINE 3, LRE and Reflector; and was able to range to the magnetically-stabilized northern-hemisphere-preferring satellite Beacon Explorer C far more often than expected. For these superior performances it won the AUSLIG Excellence Award in October.

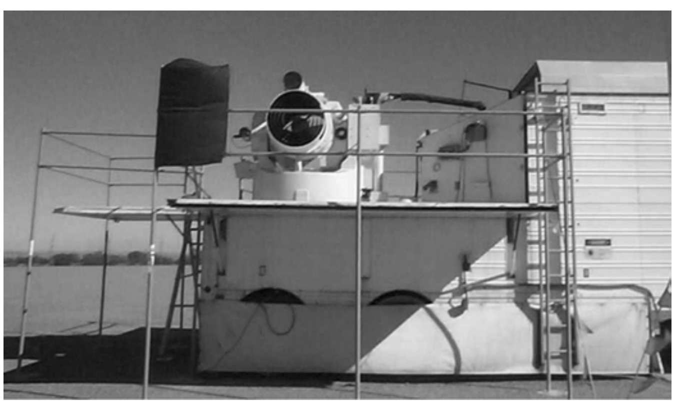


Figure 4.3-1. MOBLAS-5 Station, Yarragadee, Australia. Staff members (left to right): Peter Bargewell, Vince Noyes, Randall Carman, Brian Rubery, Jack Paf

The full local tie survey was repeated in April 2001. It connected the intersection of axes to ground marks, calibration targets, GPS, GLONASS, DORIS and timing antennae. A new feature was connection to a leveling mark for absolute gravity meters, for which a brick building was constructed in April on the concrete slab on which a 30-foot communications tower once rested. The report is available at:

http://www.auslig.gov.au/geodesy/techrpts/pdf/techrep4.pdf

The new absolute gravity site was occupied in June 2001 by an FG-5 absolute gravity meter. All the other space geodesy instruments operated nominally.

A kangaroo hopped around inside the compound in December causing minimal damage to itself, and the cleaner's car caught fire. It was not recorded whether the two incidents were related.

Key Point of Contact

P.O. Box 137
Dongara Western Australia 6525
AUSTRALIA

Voice +61 (0)8 99291011
Fax: +61 (0)8 99291060
Email: moblas@midwest.com.au

MOUNT STROMLO

This station underwent several planned interruptions during 2001, nevertheless its performance was highly respectable, acquiring 3148 LEO, 870 LAGEOS-1 and -2, and 397 high satellite passes for a total of 4415 passes for the calendar year. A small deterioration in the station's ranging precision was noticed in this period, possibly due to a subtle problem with the laser.

Overall, weather was worse than usual, with much high cloud limiting high-satellite opportunities. The whole observatory was closed by bushfires on Christmas Eve and Day, but fortunately sustained no damage. Ladybird swarms affected the system in March, which triggered extensive repairs to the dome (which automatically follows the telescope). The elevation axis was completely rebuilt to improve tracking stability over a month in October/November, and plans were finalized to rebuild the azimuth axis and re-survey the local ties early in 2002.

The operating contractor, Electro Optic Systems, by agreement, uses Mt. Stromlo station for testing its space debris tracking development programs. Electro Optic Systems received a new R&D grant during the year. The resulting increase in such activity had a small effect on SLR productivity, but successfully ranged to quite small particles with the High Energy Laser, as predicted in several papers presented at the Matera ILRS Workshop.

Figure 4.3-2. The Mount Stromlo Station, Australia station and staff (left to right): Dr. Chris Moore, Mark Elphick, Bill Bane.

Key Point of Contact

Electro Optic System Pty Limited
Locked Bag 2
Post Office, Queanbeyan
NSW 2620
AUSTRALIA

Station voice: (61) 02-6287 2953
Station fax: (61) 02-6287 2951
EOS voice: (61) 02-6299 2470

PORTABLE SATELLITE LASER RANGER (PSLR)

The PSLR has been restored to an operational state in the Department of Applied Physics at Curtin University, Perth. Replacement of key components has been completed, and a re-write of the control software is underway to integrate the upgraded components and to allow porting to other operating systems, specifically Linux. The PSLR should have full tracking capability in 2003, and it is hoped to tested at Yarragadee.

CHINESE STATIONS

BEIJING

Wang Tanqiang,, *Research Institute of Surveying and Mapping*

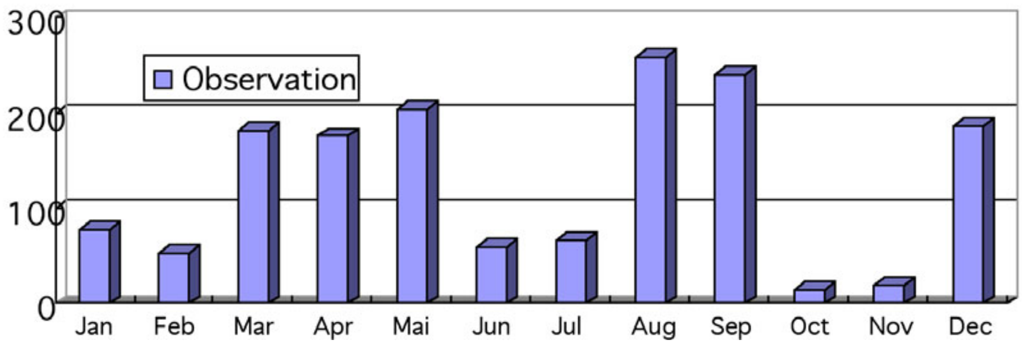


Figure 4.3-3. Observations from the Beijing SLR site in 2001.

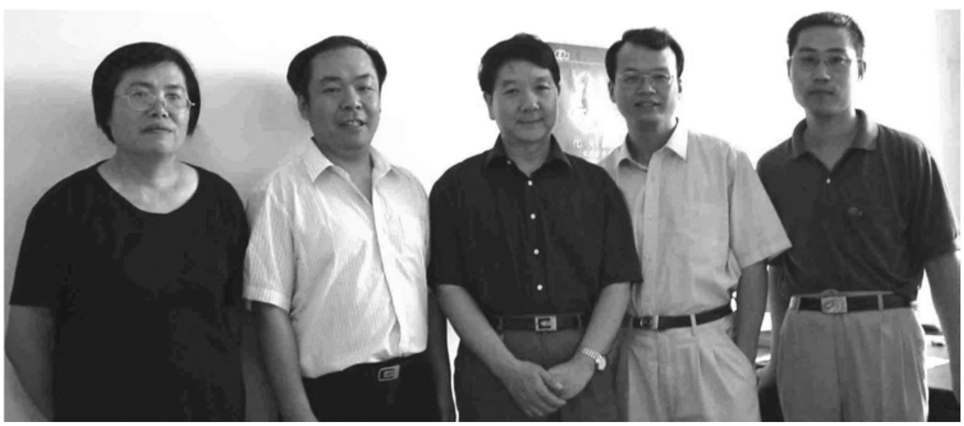


Figure 4.3-4. The whole Staff in Beijing SLR Station

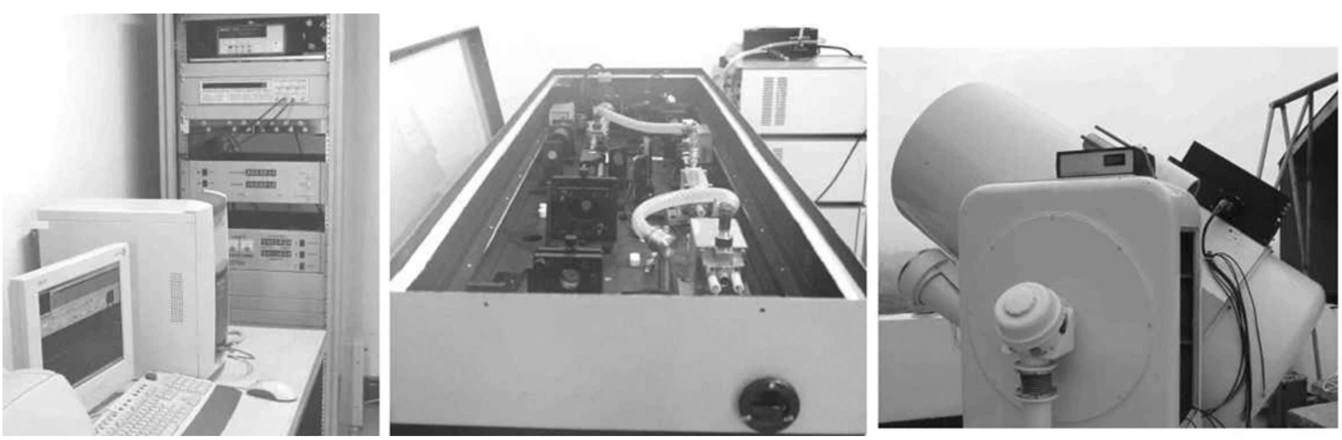


Figure 4.3-5. The new SLR system to be installed in San Juan, Argentina, will be ready before the end of 2002

Key Point of Contact

Wang Tanqiang
Chinese Academy of Surveying and Mapping
16 Beitaiping Road
100039 Beijing
CHINA

Voice: 010-68212277-255
Fax: 010-68218654
Email: wangtq@163.net
Email: wangtq@263.net

CHANGCHUN

You Zhao, Cunbo Fan, Chengzhi Liu, *Changchun Observatory*

Changchun Observatory has updated its satellite laser ranging (SLR) system since 1997, including satellite orbit prediction, tracking, data collection, data preprocessing and data delivery. After the system update, the single-shot precision improved from 5-7 cm to 1-2 cm for satellites and from less than 1 cm for ground targets. The normal point precision reached 4-7 mm. In recent years, the amount of observation data has increased dramatically. Each year, more than 2000 passes data were obtained, and, in 2001, 3438 passes data were obtained, a record for the Changchun SLR station.

In addition, the system stability has been greatly improved. According the to report issued by International Laser Ranging Service (ILRS), the long-term and shot-term stability of the SLR system has become better and better. The long-term stability improved to 1 cm or better from 4 cm and the short-term stability improved to 2 cm from 6 cm.

The Changchun station has become a very important participant in the international SLR Network.

- Receiving System: The C-SPAD with time walk compensation circuit and the temperature control shell was adopted as photo-electronic detector instead of the old PMT. The features of C-SPAD are high quantum efficiency, low time walk, automatic compensation and low working voltage. The C-SPAC decreased the system ranging bias caused by the variation of return signal amplitude and has larger dynamic range.
- Timing System: HP58503A GPS time frequency receiver supplies the primary 10 MHz signal and the second pulse that synchronizes the control system and receiving system to GPS time. The tracking software was improved to synchronize time automatically for each pass to reduce time walk and enhance the stability of timing system.
- Servo System and Encoder Electronics: A new servo system for the mount was built. As some microprocessors were substituted for the old relays, the stability improved. The new servo system adopted IGBT improving the tracking capability for low orbit satellites, and the tracking error for high orbit satellite apparently was diminished. The new encoder electronics uses a circuit with 23 bit (0.155”) resolution, improving the output signal. Also, the output signal of the encoder is less affected by the intensity variation of encoder light. So the encoder is more stable.
- Laser system: A Nd:YAG laser was adopted for satellite laser ranging. Some procedures were adopted for system safety so that the laser could work continuously and automatically.
- Meteorological Sensor: The barometric has a resolution of 0.01mbar and, an accuracy 0.1mbar/year. The meteorological data is read automatically for each pass.
- Satellite Prediction and Pre-processing Software: A new prediction software for satellites was introduced improving prediction accuracy. The prediction accuracy of range for low orbit satellite approached 20 m and was better for LAGEOS. Accurate position prediction has helped to increase the return rate from satellite. The accurate ranging predictions allowed the narrowing of the range gate and reduced the interference from background noise. The data pre-processing screens the raw data and generates normal points for precise orbit determination and other applications. Occasionally the laser produces double pulses, which might introduce a rang biases. We developed special software for detecting and repairing double pulses.

The Changchun Observatory is developing daylight tracking capability, and performing research in data analysis and applications. A new control system is being adopted to further improve data quality and quantity.

The following are photos of Changchun SLR site and staff:

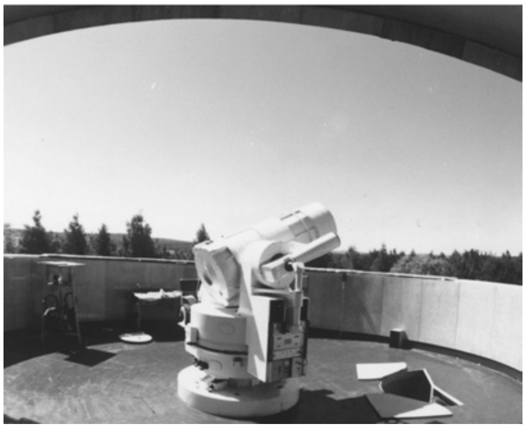
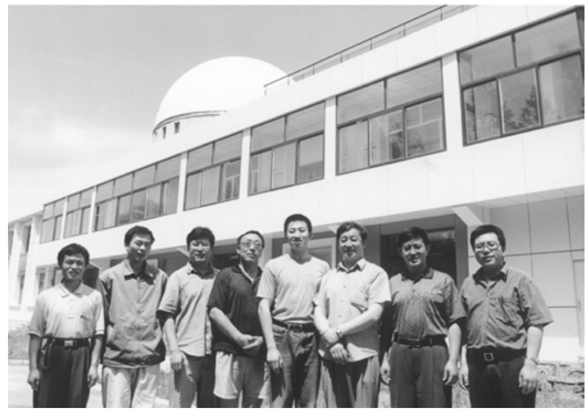



Figure 4.3-6. The Changchun SLR telescope; The staff group, from left to right: Cunbo Fan, Yong Cheng, Xingwei Han, Xinhua Zhang, Haitao Zhang, Jiangyong Shi, You Zhao, Chengzhi Liu. The backgroud of the photo is the SLR building after new decoration.

Key Point of Contact

You Zhao
Changchun Jing Yue Tan Xi Shan
Changchun Observatory of CAS
Changchun, 130117
CHINA

Voice: +86-431-4511337, 4517112, 4513550
Fax: +86-431-4513550
Email: ccslr@public.cc.jl.cn
youzhao@public.cc.jl.cn

KUNMING

Wu Wang, *Yunnan Observatory*

The Kunming SLR station acquired about 1100 passes in 2001. Most were collected in Jan-May. From June through October the weather was almost always cloudy or rainy. In spite of the down time, station data yield continues to improve. We overcame some difficulties in 2001, a thunderstorm caused major system damage.


Figure 4.3-7. The Kunming SLR station and staff.

In the future, the system will be configured for tracking low satellites, and for daylight tracking.

Key Point of Contact

Yaoheng Xong, Head, Kunming Station, Wu Wang, Chongguo Jiang
Yunnan Observatory Voice: 86-871-3911347(O)
Kunming 650011 Email: yozsx@public.km.yn.cn
CHINA

SHANGHAI

Yang Fumin, *Shanghai Observatory*

The most important event for the Shanghai SLR Station in 2001 was acquiring a piece of land to build the new observatory (Figure 4-3.9). Construction on the present observatory began in 1982, and it was put into operation in November 1983 in time for the MERIT Campaign. The observatory was a temporary and simple one. It has taken more than ten years to get permission from the local government for a plot of land that is located on the top of the Sheshan hill beside the 1.56 meter optical telescope. The distance between the new site and old one is about 400 meters. The construction has begun and will be completed the end of 2002. The present SLR instrument will be moved into the new observatory by the spring of 2003.

Figure 4.3-8. Drawing of the new Shanghai SLR Station

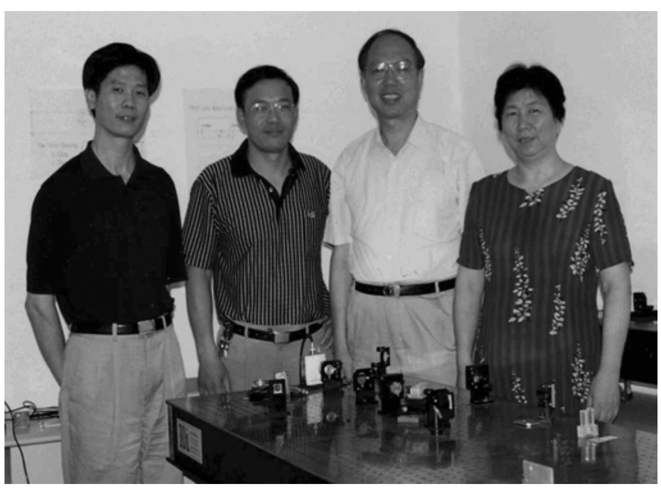


Figure 4.3-9. Photo of part of the staff of the Shanghai SLR station. From left to right: Chen Juping (electronics), Zhang Zhongping (software and data management), Yang Fumin (head of the group) and Chen Wanzhen (laser and mechanics). Two observers are not shown in the photo.

Key Point of Contact

Yang Fumin	Voice: +86-021-64696290
Shanghai Astronomical Observatory	Fax: +86-021-64384618
The Chinese Academy of Sciences	Email: yangfm@center.shao.ac.cn
80 Nandan Road	
Shanghai 200030	
CHINA	

TROS

Guo Tangyong, *State Seismological Bureau*

In 2000, the construction began on TROS by Institute of Seismology, China Seismological Bureau. A series of test were done at the Wuhan site. The results of tests showed that the system performance met the design specifications:

Table 4.3-1. TROS System performance.

Parameter	Value
The max range	20000 km
Single shot precision	20mm
Laser energy	15mj
Wavelength of laser	5320A
Max Slew Rate Az & El	5deg/s
Max. Repetition Rate	10[Hz]
Receiving Aperture	375mm

The TROS began tracking in August 2000 and stopped in October 2001 at the Beijing SLR Station. TROS moved to the Urumqi site where it began tracking in April 2001. Then TROS moved to the Lhasa site where it began tracking in august 2001. The passes are summarized in Table 4.3-2.

Table 4.3-2. Passes tracked by the TROS System beginning in October 2001.

Site	Beijing 7343	Urumqi 7355	Lhasa 7356
L1 & L2	42	44	120
Total passes	344	87	241

Figure 4.3-10. TROS at the Lhasa SLR site, and at the Urumqi site from April 15-June 12, 2001.

Figure 4.3-11. The performance evaluation meeting for TROS in Sep. 2001 at the Lhasa site.

Figure 4.3-12. The TROS is prepared to track satellites at the Lhasa site.

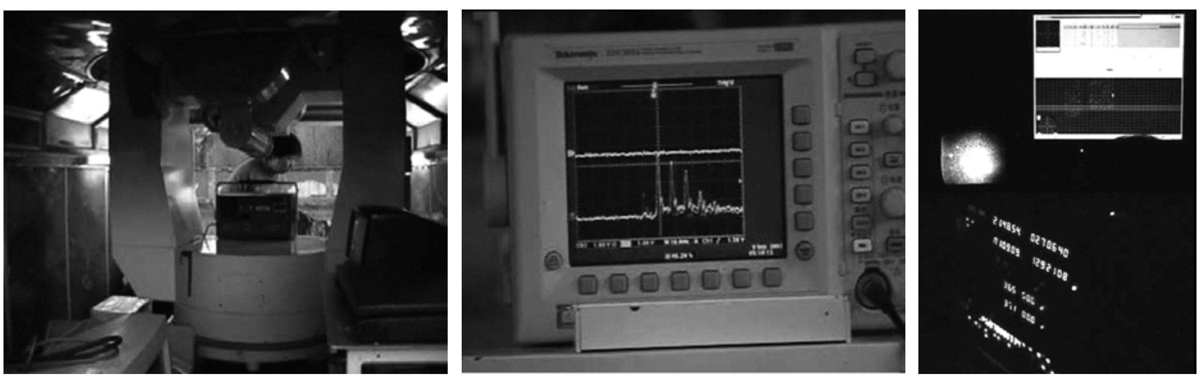


Figure 4.3-13. Operator checking equipment before beginning tracking; laser's wave form on the oscilloscope; tracking informations.

Key Point of Contact

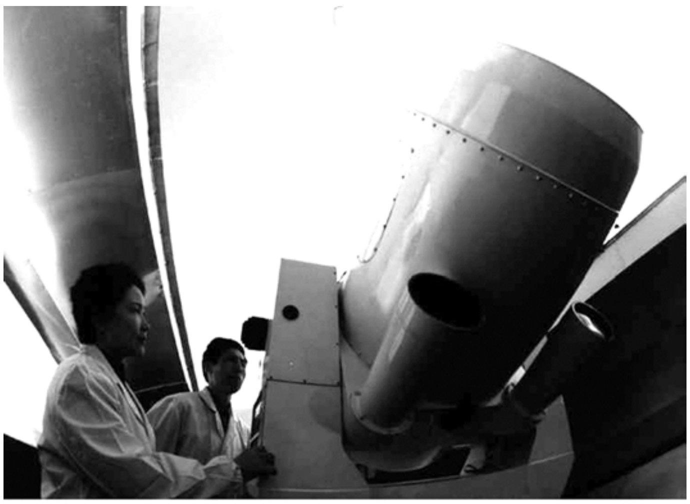
Guo Tangyong
No. 70, Central Xiaohongshan District
Wuhan, 430071
CHINA

Voice: 8602787863471
Email: whslr@public.wh.hb.cn

WUHAN

Guo Tangyong, *State Seismological Bureau*

In 2001, the Wuhan SLR station stopped tracking for upgrades of the tracking door and the dome. For subsequent tracking work, the entire system will be checked or updated. Daily tracking work will be begin towards the end of 2002.



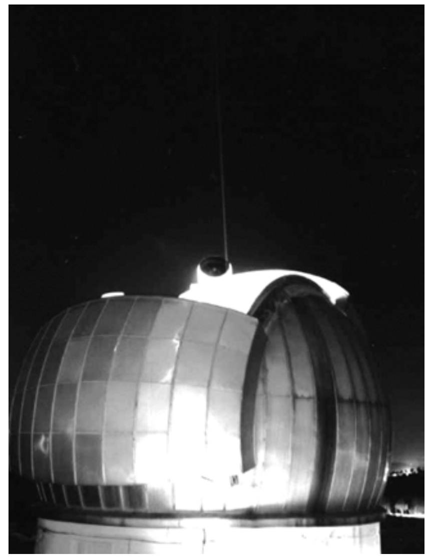


Figure 4.3-14. Operator adjusts the SLR receive equipment; Wuhan night ranging.

JAPANESE STATIONS

SIMOSATO

Masayuki Fujita, *Hydrographic Department/Japan Coast Guard*

The Simosato Hydrographic Observatory (figure 4.3-16 below) is located in the bucolic area of central Japan; it is about four hours by the train from Osaka, the second largest city of Japan. Since it is close to the Pacific coast, the meteorological conditions do not always allow laser tracking.

The observatory has currently six staff members including the director. In April four members of the observatory staff were replaced. Every night, the satellite tracking observations were being carried out by two staff members.

The SLR tracking system undergoes regular maintenance by the professional staff six times a year. Comprehensive maintenance is performed twice a year. Very few components of the system were upgraded and/or repaired in 2001. In April, a small problem occurred in the transmitter, but it was repaired in May. In August, the servomotor and encoder controlling the azimuth and elevation axes of the telescope had to be replaced. In December, the start pulse detector was replaced with a photo detector with 50ps resolution. Nevertheless, some portions of the system, such as the telescope, parts of the controlling and signal receiving electric circuits, are still composed of the original parts introduced in 1982 and need to be replaced to attain higher quality observations.

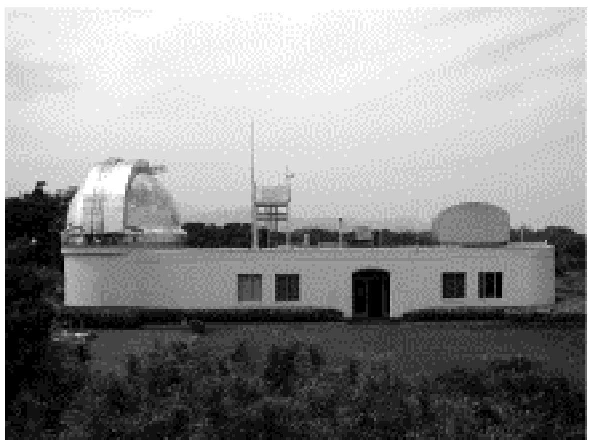


Figure 4.3-16. Simosato Hydrographic Observatory.

Key Point of Contact

Koich Fuchida Chief, Simosato Hydrographic Observatory
Koji Kawai Deputy chief
Simosato Hydrographic Observatory
1981 Simosato Nachi-katuura Town
Higashimuro District
Wakayama Prefecture 649-5142
JAPAN

Voice: +81-735-58-0084
Email: simosato@oak.ocn.ne.jp

Russian Stations

Natalia Parkhomenko, *SRI for Precision Instrument Engineering*

Komsomolsk

Station operations will discontinue from July, 2002 through the end of 2002 for modernization of the telescope, tracking system, laser, distance measurement systems.

Figure 4-3.17. Komsomolsk Site.

Maidanak, (1863 and 1864), and Mendeleevo

These systems were operational in 2001.

Figure 4-3.18. Maidanak SLR Stations; Mendeleevo Site

SLR station near the Moscow

The station makes regular ranging measurements, but we still do not have permission for the station to participate in the ILRS; we will continue our efforts to obtain the permission.

Figure 4-3.19. SLR station near the Moscow.

Key Point of Contact

Natalia N. Parkhomenko
IPIE
111253, Moscow, Aviamotornaya 53
RUSSIA

Voice: 7 095 362 2470
Email: Natalia.N@g23.relcom.ru

The MCC-M is regularly making estimations of the station's ranging precision (Table 4.3-3). Besides this, IPIE is currently conducting several experiments in space to solve some SLR problems.

Table 4.3-3. Russian Mission Control Center Residual Analysis Report

Residuals are summarized for the following 3-day arcs: wtd rms(cm)

LAG-1 LAG-2	3-DAY ARC	02/06/30 12.00 - 02/07/03 12.00	1.6
LAG-1 LAG-2	3-DAY ARC	02/07/01 12.00 - 02/07/04 12.00	1.6
LAG-1 LAG-2	3-DAY ARC	02/07/02 12.00 - 02/07/05 12.00	1.8
LAG-1 LAG-2	3-DAY ARC	02/07/03 12.00 - 02/07/06 12.00	2.1
LAG-1 LAG-2	3-DAY ARC	02/07/04 12.00 - 02/07/07 12.00	1.9
LAG-1 LAG-2	3-DAY ARC	02/07/05 12.00 - 02/07/08 12.00	1.6
LAG-1 LAG-2	3-DAY ARC	02/07/06 12.00 - 02/07/09 12.00	1.9
LAG-1 LAG-2	3-DAY ARC	02/07/07 12.00 - 02/07/10 12.00	1.6
LAG-1 LAG-2	3-DAY ARC	02/07/08 12.00 - 02/07/11 12.00	1.8
LAG-1 LAG-2	3-DAY ARC	02/07/09 12.00 - 02/07/12 12.00	1.8
LAG-1 LAG-2	3-DAY ARC	02/07/10 12.00 - 02/07/13 12.00	1.7

Shelkovo (1111 NP)

	DATA	T ini	T fin	SC	TTL	INC	ME	RMS	ORMS	ELEV	T	P	H	CALIB	TB	RB	PRMS	SCI
							mm	mm	mm		deg C	mbar	%	mm	us	mm	mm	
1111	04.07.02	00:53	01:16	L1	10	07	-42	20	50	032-060	17	1003.9	61	27609	12	-33	4	0
1111	04.07.02	20:03	20:25	L1	06	05	-17	25	30	041-070	21	1001.9	52	27610	0	-17	25	0
1111	04.07.02	23:35	00:00	L1	08	08	-52	37	68	039-055	19	1001.9	59	27610	-17	-56	22	0
1111	08.07.02	21:37	22:02	L1	07	05	-6	10	12	034-067	19	996.9	86	27609	0	-6	10	0
1111	12.07.02	19:47	20:06	L1	07	05	-14	17	22	054-073	22	999.9	63	27611	-10	-17	3	0
1111	12.07.02	23:09	23:39	L1	10	06	-25	10	29	025-062	17	1000.3	83	27610	5	-21	7	0

Adopted abbreviations

Date - Day, Month, Year;
Tini,Tfin - Time Interval of Passes (hh:mm);
SC - Spacecraft Name;
TTL - Total Measurements Number in the Pass;
INC - Included Measurements Number in the Pass;
ME - Math.Expectation;
RMS - Root Mean Sguare for ME;
ORMS - Root MEAN Sguare for the Orbit;
ELEV - Elevation Angles (min-max)
T - Temperature, Celsium degrees;
P - Atmospheric Pressure, mbar;
H - Huminity, %;
CALIB - Calibration Delay Shift, mm;
TB - Time Bias, microsec (if TB = " * ", then no estimate for TB);
RB - Range Bias, mm (if RB = " * ", then no estimate for RB)
PRMS - Precise RMS for Approx. Polynomial, mm;
SCI - System Configuration Indicator;

Spherical retroreflector on board of the METEOR-3M(1) satellite

Most of the passive SLR satellites have been launched during the years when the SLR station equipment provided an accuracy of several centimeters. But now, with the new equipment providing an accuracy of several millimeters, the systematic target errors caused by the retroreflector design and their distribution over the satellite surface are limiting the distance measurement precision.

On board of the METEOR-3M(1) satellite, a novel-type retroreflector is installed, having an unique design based on the spherical Luneberg lens principle. It has a spherical symmetry, and a constant CoM correction value with an accuracy of about ±0.02 mm. In contrary to currently used cube corner prism retroreflectors, this retroreflector has a practically zero target error.

Starting from December, 2001, a joint experiment is conducted by GSFC and IPIE on laser ranging of the "Optical Luneberg Lens" on board of the METEOR-3M(1)spacecraft. Two American SLR stations (Greenbelt and Monument Peak) and one Russian station near Moscow are taking part in the experiment. The limited number of stations participating in the experiment was caused by fear that laser light may cause interference during operation of the SAGE instrument installed by NASA on board of the METEOR-3M(1) spacecraft. Currently all the limitations have been lifted, and we are asking the ILRS for support of the METEOR-3M(1) mission with the spherical retroreflector on board.

OTHER STATIONS

RIGA

Kazimirs Lapushka, *Astronomical Institute of the University of Latvia*

Besides performing routine ranging operations, characterization of the new event timer and a rapid signal amplitude measuring system continued. We also preformed a calibration system upgrade and stabilization.

Some mechanic, electronic and optical components were added to the system to maintain a low-noise system status as much as possible to prepare the system for daylight ranging in the 2002.

Some modifications to the system software were introduced to increase the drive precision of the laser telescope and data pre-processing quality.

The signal processing group from the Institute of Electronics and Computer Science of the University of Latvia has continued design and investigation of a new upgrade to the event Timer MOTIC (Modular Time-Interval Counter). One component of this program was a comparison of MOTIC, STANFORD and P-PET system timers which was carried out at the Potsdam and Wettzell SLR stations at the end of 2001. Results of that comparison showed that MOTIC and P-PET timers are really in the same class of precision instruments.

Figure 4.3-20. Riga station staff (**left to right*****): K. Lapushka, I.Abakumovs, V.Laposhka.***

Key Point of Contact

Kazimirs Lapushka
Boulevard Rainis 19
LV-1586, Riga
LATVIA

Voice: 371 7611984
Fax: 371 7611984
Email: riglas@lanet.lv

SIMEIZ

Shtirberg L.S., Tatevian S.K., Dmitrotsa A.I., Nejachenko D.I., Minin O.A., Filikov S.V. *Simez*, Michael R. Pearlman, *SAO*, Daniel Nugent, *HTSI*

In 2001, upgrade of the Simiez SLR station continued under a grant from the US Civilian Research and Development Foundation (CRDF) in cooperation with the Smithsonian Astrophysical Observatory. Equipment was purchased under the grant and installed by station personnel. The station software was also substantially rewritten to connect all of the major subsystems. The upgrades included Farrand Controls angular encoders for the mount, a new Hamamatsu H6533 photomultiplier, an HP5370B time interval unit, a black and white CCD to aid acquisition, a new Pentium-2 computer and interface cards. During the year, with the system improvements, the station acquired 550 satellite passes, ninety-six of which were on LAGEOS. The main issue remaining is the laser, which has severe reliability problems and has a relatively wide pulse width of about .4 nsec.

Figure 4.3-21. The Simeiz SLR Station.

By agreement between NASA and the Crimean Astrophysical Observatory, a new IGS station (CRAO) was set up in Simiez. An SNR-8000 GPS was installed just in front of the SLR station. Aside from supporting the IGS network, the new GPS also provides timing for the SLR.

In 1999 the Simiez SLR stations was included in the list of national facilities in the Ukraine, qualifying it for some funding for further improvement.

Key Points of Contact

Dr. Lazar Shtirberg	Email:	larik@simeiz.ylt.crimea.com
Andriy Dmytrotsa	Email:	dmytrotsa@fastmail.fm
Sergey Filikov	Email:	filikov@simiez.ylt.crimea.com
Crimean Astrophysical Observatory	Voice:	38 0654 240141
Observatory str. 1	Fax:	38 0654 40704
Simeiz, Yalta	Email:	lazar@crao.crimea.ua
Crimea, 98680	Email:	lazar@simez.ylt.crimea.com
UKRAINE	Email:	simiez@mail.ylt.crimea.com

SALRO

Turki Al-Saud, Abdallah Azzeer and John Guilfoyle, *KACST/Institute of Space Research*

Figure 4.3-22. SALRO tracking station.

The SALRO site at the Solar Village, Saudi Arabia. The Solar Village is about 45 km north west of Riyadh.

Photograph was made July 9, 2002, while tracking the Etalon-2 satellite after dusk.

The site has many shrubs and hedges, giving it the feel of an oasis in the desert.

The site is operated primarily during daylight and early evening hours.

Re-Commissioning in 2000

KACST issued an O&M contract in mid 2000 with the aim of making SALRO operational once again, after it sat unused for some time. Several months were spent in 2000 making all equipment operational.

Spares from the defunct Orroral Observatory and the CRL 1.5 m SLR system were used in this effort, and thanks go to those organizations for their assistance.

By the end of 2000, SALRO was capable of successful SLR to satellites in all orbit categories, except the very lowest – a limitation of the mechanical transmit/receive system which remains.

While the entire system received attention to varying degrees, it was the laser, receiver and pulse-handling electronics that required the most work. The acquisition software had previously been upgraded by EOS to deal with the Y2K problems.

The team consists of two KACST staff trainees and two expatriate engineers working under the O&M contract.

Operations Commence January 1, 2001

With all the gross problems cleared, use of the system commenced on a production basis. Operational procedures were developed in tandem with fine tuning of the system. Staff training assumed a higher priority. One observations shift operated all year.

2001 was a transitional year, commencing as "engineering" and ending by achieving compliance with all the ILRS guidelines.

Some periods of down-time exceeding one week were required to overcome random failures, and implement major improvements such as the installation of a new compensated SPAD detector. The incidence of failures and unscheduled down-time is now minimized with the implementation of a preventative-maintenance program.

Winter: mid December to mid March. Cold, with very clear skies quite often. Occasional rain, some cloud periods lasting several days. Generally good SLR conditions day and night, routine daylight GPS acquisitions possible.

Autumn: October to mid December. Cooler, generally clear. Good SLR conditions day and night.

Summer: mid June through September. Generally clear, with varying degrees of sky haze at all times.

Day: high temperatures and directed sunlight on the telescope make SLR operations difficult.

Night: no problems, including occasional GPS acquisitions.

Spring: mid March to mid June: Difficult SLR conditions, day and night. Increasing daytime temperatures, very hazy at times, occasional cloud periods lasting several days – generally unsettled.

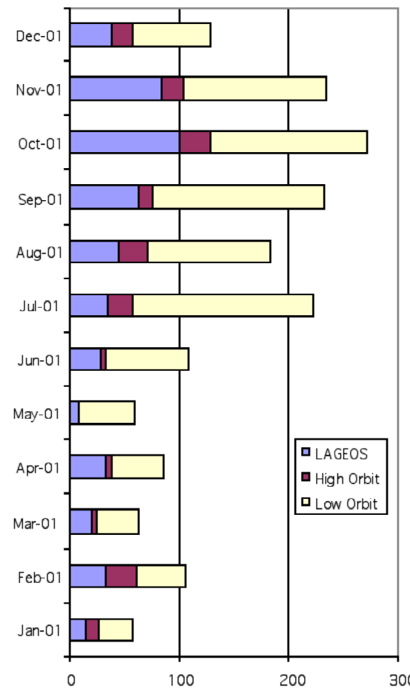


Figure 4.3-23. SALRO tracking station.

Plans

- boost productivity by expanding operations to cover 2 shifts 5 days per week.
- re-survey the site, work to remove any residual errors in adopted site coordinates.
- analyze and tune to eliminate systematic errors, range biases, etc.
- engineering improvements to the telescope (sun shields), AC/refrigeration systems, etc.
- site development to include analysis capability, GPS calibration etc.

Conclusions

- KACST have a firm commitment to continue and develop SALRO operations, raising the profile of this science and its derivatives within the organization.
- environmental conditions allow useful operations all year round, with peak performance occurring in autumn and winter. (see Figure 4.3-23)

Key Points of Contact

Dr. Turki Al Saud
KACST
Space Research Institute
PO Box 6086
Riyadh 11442
SAUDI ARABIA

Voice: +966 1 481 3560
Fax: +966 1 481-3523
Email: salro@kacst.edu.sa

4.4 LUNAR NETWORK

Peter Shelus, *University of Texas*

INTRODUCTION

The Lunar Laser Ranging (LLR) network consists of the Observatoire de la Cote d'Azure (OCA) station in France and the McDonald Laser Ranging Station (MLRS) in the USA. Both stations operate in a multiple target mode, observing SLR targets in addition to the lunar surface retroreflectors. The Matera Laser Ranging Observatory (MLRO) is also a joint SLR/LLR station, still in the testing and verification stages for LLR, after being installed in Matera, Italy. There were no LLR data reported by the Wettzell SLR station in Germany.

There is new LLR-related activity going in the United States at the Apache Point Observatory in New Mexico. Work is progressing on the implementation of a completely new LLR station. A laser has been ordered and other equipment is being put into place. Presently, they are concentrating most intently on detector and timing electronics. Their belief is that that a 3.5-m telescope and 1 arcsecond image quality at their site, will produce a high photon-rate regime, able to achieve millimeter precision in a matter of minutes. The University of Washington research group is optimistically looking forward to sending first photons skyward before the end of 2002.

OBSERVATOIRE DE LA COTE D'AZUR (OCA)

Jean-Francois Mignard, *OCA, CERGA*

The OCA station, located in the south of France on the Calern Plateau near Grasse, performed well in 2001. On the technical side, there were no major incidents. However the data yield was a bit lower than desired due to exceptionally bad weather during the year. As mentioned in last year's report, the OCA observing program is no longer a lunar only one. It is divided among the four retroreflectors on the Moon, the two LAGEOS targets, and the several high altitude artificial satellites (GLONASS, Etalon, and GPS).

The OCA station netted 350 normal points on the Moon in 2001 (down from 830 in 2000), a 10-year low. The retirement (uncompensated) of one scientists and observers negatively impacted the observing program. For safety reasons, a single pulse of about 200 mJ is now used instead of a two-pulse-train of 250 mJ. This also contributed to the lower data yield. An ongoing study is aiming at using the two polarizations of the laser beam to double the energy per pulse fired to the Moon, without hazard to the laser. This improvement is now being implemented and should increase the data yield during poor weather times. A major refurbishing of the steering of the dome was undertaken early in 2002, leading to a break in OCA observations for several weeks.

Validated OCA LLR data are made available through the data centers of the ILRS and can also be retrieved from the OCA local web-site, with a monthly update, in both the old and new formats. Quick distribution (within 2 days) is also guaranteed to associated teams in Europe and in the US. The Paris Observatory Lunar Analysis group has been very active in exploiting the LLR data for Earth rotation, the dynamics of the Moon and the links of reference frames with significant publications in these areas.

The annual funding of the OCA station remains fragile and was, in fact, trimmed in early 2002. However, including other targets in the routine observing program allows the station to augment its main funding with additional support from the national space program, a much more secure solution for the future. A major review of OCA activity should occur either in 2003, or early 2004, which could lead to an important internal reshuffling of the activities between the artificial satellite and the lunar stations on the plateau.

Regarding the artificial satellite observations being made with the lunar station, the targets are limited to LAGEOS I and II as well as artificial satellites of higher altitude (GPS, GLONASS and Etalon). More than 6,500 normal points have been produced for the two LAGEOS targets and 3,000 for the others (1,200 for Etalon–1 and -2, 700 for the GLONASS satellites and 1,000 for GPS 35 and 36). A dedicated campaign involving the artificial satellite station, the lunar station and the mobile station was carried out in the fall of 2001 in order to assess the systematic differences among the three stations and determine the accuracy of the renovated mobile station before a 6-month calibration campaign on Jason-1. One should also note the successful OCA search for the Japanese satellite LRE as a result of a sustained campaign of several months due to lack of precision of the ephemeris. The station was officially acknowledged with a recognition award presented by the Japanese Space Agency.

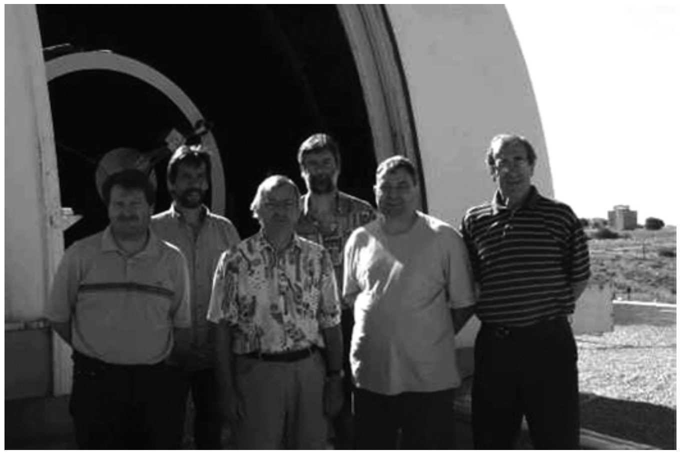


Figure 4.4-1. The team of the Grasse LLR (left to right) in front: Maurice Furia, Jacques Depeyre, Jean-François Mangin, Jean-Marie Torre, Dominique Féraudy, Gérard Vigouroux .

Key Points of Contact

Jean-Francois Mangin
Observatoire de la Cote d'Azur
Avenue Copernic
F06530 Grasse
FRANCE

Voice: ++33-0493405362
Fax: ++33-0493405333
Email: mangin@obs-azur.fr

MCDONALD LASER RANGING STATION (MLRS)

Peter J. Shelus, University of Texas

McDonald Observatory laser ranging station, MLRS, is located in the mountains of west Texas, near Fort Davis, and continued its LLR activities during 2001. LLR data volume was approximately the same as it was during the previous year. Although some responsibility can be claimed for several equipment problems throughout the year, the poor weather continues to be mainly responsible for the less than desired LLR data yield. Similar to the OCA station, the MLRS observing program is not lunar only and the station ranges to most ILRS artificial satellite targets. Total data yield for the MLRS, including the Moon, were 3,534 total passes (up from 3,174 total passes), 37,498 normal points (up a bit from 37,057 normal points), and 34,384 minutes (up from 31,687 minutes) of tracking data.

The MLRS station netted 92 lunar normal points in 2001 (up slightly from 89 in 2000). MLRS LLR data are made available through the data centers of the ILRS. All data is transmitted to the data centers in near-real-time, using standard SLR formats.

Because of a very tight financial situation, there have been no upgrades or improvements at the MLRS. Activity is directed toward keeping the station operational and in a data gathering mode.

Key Points of Contact

Peter Shelus
McDonald Observatory
Department of Astronomy
The University of Texas at Austin
Austin, TX 78712
USA

Voice: (512) 471-3339
Fax: (512) 471-6016
Email: pjs@astro.as.utexas.edu

SECTION 5

OPERATIONS CENTER REPORTS

SECTION 5 - OPERATIONS CENTER REPORTS

5.1 Mission Control Center

Vladimir Glotov, *Russian Mission Control Center*

The MCC activity as an Operation Center of the Russian SLR network started in 1990. MCC controls five operational SLR stations now: Maidanak-1, Maidanak-2, Komsomolsk, Mendeleevo, Katzively (partially). The MCC Operation Center also participates in the regular testing of new SLR station Shelkovo (near Moscow). The MCC's main tasks, as the Operation Center of the Russian SLR network are:

- Delivery of satellite predictions, tracking schedules and technical information to SLR stations;
- Daily satellite prediction generation for Reflector and Meteor-3M
- Collection, quality check, failure detection of raw SLR data in FR format from tracking stations; NP generation for all stations and satellites;
- Transferring SLR data to the IRS Global Data Centers (EDC, CDDIS)
- Permanent (daily) monitoring of SLR stations data quality, cooperation with the station developers (RISDE - Head Russian SLR stations development) and staff in the analyses of station failures.

The 2001 SLR tracking results for the Russian network for low satellites, high satellites and GLONASS are shown in Table 5.1-1.

Table 5.1-1. Data Yield from the Russian SLR Network.

Site Name	Sta	ER2	BEC	STA	WES	GFO	TPX	AJI	STE	CMP	Total
Komsomolsk	1868	0	11	15	0	1	21	30	3	0	81
Maidanak-2	1864	2	3	8	0	1	25	19	2	0	60
Maidanak-1	1863	1	0	1	0	0	5	5	0	0	12
Mendeleevo	1870	48	0	11	23	48	54	41	37	16	278

Site Name	Sta	G36	L1	L2	ET1	ET2	G78	G80	G84	Total
Komsomolsk	1868	0	18	9	3	1	3	8	1	43
Maidanak-2	1864	1	30	9	1	1	5	7	0	54
Maidanak-1	1863	3	6	9	4	6	1	4	0	33

KEY POINTS OF CONTACT

Coordinator of the work Vladimir Glotov cnss@mcc.rsa.ru

Person responsible Michael Zinkovsky cnss@mcc.rsa.ru

Administration support Sergey Revnivych cnss@mcc.rsa.ru

5.2 NASA Goddard Space Flight Center

David Carter, *NASA Goddard Space Flight Center*
Scott Wetzel, *Honeywell Technology Solutions, Inc.*

The NASA SLR Operational Center provides oversight responsibilities for all components associated with NASA SLR network control, including sustaining engineering, and logistics. The NASA SLR Operational Center also oversees ILRS mission operations and ILRS and NASA SLR data operations.

NASA SLR network control and sustaining engineering tasks include technical support, daily system performance monitoring, system scheduling, satellite prediction generation, operator training, station status reporting, system relocation, logistics and support of the ILRS Networks and Engineering Working Group. These fundamental activities provide the infrastructure necessary to meet or exceed all NASA SLR and ILRS mission goals and requirements.

ILRS mission operations tasks include mission planning, mission analysis, mission coordination, development of mission support plans, and support of the ILRS Missions Working Group. These activities ensure that all new mission and campaign requirements are successfully and efficiently coordinated with all participating organizations.

Global Normal Points (NP data), NASA SLR fullrate data, and satellite predictions are also managed as a function of data operations. In addition, NASA SLR data operations provide support to the ILRS Data Formats and Procedures Working Group.

Global NP data operations consist of receipt, format and data integrity verification, archiving, merging and transmission of data. The daily transmission of the global NP data to the CDDIS for scientific use remains the primary output of this process. All functions associated with NP operations are automated processes not subject to manual intervention. Maintenance and monitoring of all operational software systems, computer systems and networks are performed to confirm the reliability and accuracy of all data processing functions. Statistical analysis is also performed to compare station tracking activity with data center acquisition to assist in the identification of any potentially lost data.

Activities in NP data operations during 2001 included the implementation of the Generic Normal Point Field Processor (GNP 2.5) to field systems. This upgrade was deployed in 2001 in MOBLAS-7, located in Greenbelt, Maryland and MOBLAS-4 located in Monument Peak, California. This upgraded processing system contains superior data screening and editing techniques, reducing the production of marginal NP data by approximately 10% while increasing high quality NP data volume. The implementation of GNP 2.5 to all remaining NASA SLR field systems is scheduled for 2002.

Activities in 2001 also included a collaborative effort with the Naval Research Laboratory in the development of prediction vectors for the STARSHINE 3 satellite with increased accuracy. This successful effort has resulted in improved acquisition capabilities of the STARSHINE 3 target for SLR ground systems.

Process planning commenced in 2001 to deliver sub-daily acquisition data for several satellite missions including CHAMP, GRACE-A and GRACE-B. The incorporation of drag functions to increase prediction accuracy was also a planned future activity by NASA SLR Missions Operations

Noteworthy during 2001 was the incorporation of upgraded Target Pointing software developed for the LRE satellite-tracking mission. This software which enhances SLR ground system s ability to acquire and track satellites in Geo-stationary transfer orbits, will have beneficial applications to other current, and future satellite tracking missions.

The fullrate data product continued to be produced by NASA SLR systems and transferred to the CDDIS during 2001. Though this product was not an ILRS data requirement, fullrate was automatically received, processed and transmitted to the CDDIS on a daily basis to augment user needs and requirements.

Daily satellite predictions continue to be generated and distributed to stations and ILRS data centers (i.e., CDDIS, EDC) for every ILRS and NASA supported satellite.

The NASA SLR Operations Center is located at:

Honeywell Technologies Solutions Inc. (HTSI) / NASA SLR and VLBI
Goddard Corporate Park
7515 Mission Drive
Lanham, MD 20706, USA

HTSI has been the NASA SLR operation center contractor since November 1983, the start date of the consolidated NASA SLR mission contract.

KEY POINTS OF CONTACT

Name	E-Mail	Phone
Carter, David, NASA	dlcarter@pop900.gsfc.nasa.gov	301-614-5966
Chason, Ray, HTSI	ray.chason@honeywell-tsi.com	301-805-3962
Brogdan, Oscar, HTSI	oscar.brogdan@honeywell-tsi.com	301-805-3933
Horvath, Julie, HTSI	julie.horvath@honeywell-tsi.com	301-805-3951
Davisson, George, HTSI	george.davisson@honeywell-tsi.com	301-8053963
Donovan, Howard, HTSI	howard.donovan@honeywell-tsi.com	301-805-3985
Schupler, Bruce, HTSI	bruce.schupler@honeywell-tsi.com	301-805-3992
Stevens, Paul, HTSI	paul.stevens@honeywell-tsi.com	301-805-3960
Wetzel, Scott, HTSI	scott.wetzel@honeywell-tsi.com	301-805-3987
Steve Krietz, HTSI	steve.krietz@honeywell-tsi.com	301-805-3377

5.3 University of Texas LLR Operations Center

Peter Shelus, *University of Texas at Austin*

The very small size of the LLR network and the small number of LLR analysis centers dictate the unique nature and operational procedures of the LLR Operations Center at the University of Texas at Austin. LLR observing predictions are computed on-site at the stations and the data are automatically and electronically transferred from the observing sites to the data centers on a near-real-time basis. Analysts secure their data directly from the data centers as needed. Feedback from the analysts, when necessary, goes directly to the observing stations. Therefore, the responsibility of the LLR Operations Center is one that assures a smooth flow of data, in a form and format for obtaining the best scientific results.

Concerning work at the UT LLR Operations Center on data formats, a special study group was formed within the ILRS Data Formats and Procedures Working Group in 2000, with Ricklefs as its chair. The goal of this Working Group was to create a set of consolidated formats for ranging predictions to all current and anticipated laser targets, including passive Earth satellites, lunar reflectors, and transponders on or orbiting around the moon and other solar systems bodies or in transit. These formats are to be used by all SLR/LLR stations. During 2001, the group charter was finalized, a working document prepared, and actual work began. The working document presented the current state of affairs for predictions in the SLR/LLR communities and posed incisive questions as to the future of the process. Largely through e-mail-based discussions, several conclusions were reached: 1) predictions are to be tabular, so that an interpolator and not an integrator is used; 2) the elements of the predictions are to be geocentric state vectors, possibly in the same reference frame as existing IRVs; 3) provision is to be made for extrapolating past the end of the predictions for continued scheduling, or in the event of a network communications failure; 4) geosynchronous satellites are to be handled gracefully; 5) new on-site, but centralized, prediction software are to be developed; 6) file compression is probably necessary, due to the larger size of the prediction files. To begin with, SLR predictions would fit into the above specifications without difficulty. To identify unique LLR prediction information for inclusion, a feasibility study is under way, starting with modifications of existing lunar prediction code. Transponders present the largest source of uncertainty. Contacts are now established to solidify the unique transponder requirements. Work so far indicates a convergence to a the specific format with testing a possibility next year.

As to the LLR scheduling task, early in the experiment, the main task of the LLR program was to secure the maximum amount of data. As LLR data volume rose to reasonable levels, the UT Operations Center for LLR began to work with the stations and the analysts, seeking how best to improve the quality of the LLR data, with a bit less emphasis on mere data volume. For quality, this entails improving system calibration stability, reducing photon detection jitter, and improving the timing systems. With limited budgets at each station, these tasks can be daunting. For quantity, we look for ways to obtain more observations significantly nearer new moon and full moon. Both are important to increase the scientific payback of the LLR experiment. The UT Operations Center for LLR continues to coordinate this activity, serving as the intermediary between the observing stations and the analysis centers.

Progress has been accomplished in the LLR experiment within the UT LLR Operations Center. We are looking forward to another year of successful activity.

KEY POINTS OF CONTACT

Operations Center Manager:
Dr. Peter J. Shelus
McDonald Observatory
University of Texas at Austin
Austin, TX 78712-1083, USA
pjs@astro.as.utexas.edu

LLR Data Formats:
Mr. Randall L. Ricklefs
McDonald Observatory
University of Texas at Austin
Austin, TX 78712-1083, USA
rlr@astro.as.utexas.edu

SECTION 6

DATA CENTER REPORT

SECTION 6 - DATA CENTER REPORTS

6.1 CDDIS REPORT

Carey E. Noll, *NASA Goddard Space Flight Center*

INTRODUCTION

The Crustal Dynamics Data Information System (CDDIS) has supported the archive and distribution of laser ranging data (both lunar and satellite) since its inception in 1982. This report summarizes the activities for the year 2001 and future plans of the CDDIS with respect to the International Laser Ranging Service (ILRS). General CDDIS background and system information can be found in the CDDIS data center summary included in the 1999 ILRS Annual Report.

The CDDIS laser data archive consists of data (SLR on-site normal points, SLR full-rate, and LLR normal points), information about these data, and products derived from these data. The CDDIS is located at NASA Goddard Space Flight Center and is operational on a dedicated UNIX server. The CDDIS archive of laser ranging data and products are accessible to the public via anonymous ftp and the WWW at address:

ftp://cddisa.gsfc.nasa.gov/pub/slr and ftp://cddisa.gsfc.nasa.gov/pub /reports

DEVELOPMENTS IN 2001

SLR DATA AND PRODUCTS ARCHIVE

A summary of all data received during 2001 can be found in Section 8.

During 2001, the CDDIS continued the archive of daily and hourly SLR data files, augmenting the archive as required for new missions. The daily files are archived by satellite and year:

ftp://cddisa.gsfc.nasa.gov/pub/slr/slrql/satname/yyyy/new_qlyymmddt.allsat

The hourly files can be found in the yearly allsat directories on CDDIS:

ftp://cddisa.gsfc.nasa.gov/pub/slr/slrql/allsat/yyyy/new_qlyymmddt.allsat

where *satname* is the satellite name, ***yyyy*** is the four-digit year, ***yy*** is the two-digit year, ***mm*** is the two-digit month, ***dd*** is the two-digit day, and ***h*** is the hour (a through x). All data available in the hourly files will be delivered the following day in the daily *allsat* file as well as the individual satellite files. The hourly files are retained on-line on the CDDIS for three days after which time they are deleted. The CDDIS staff continues to create and augment merged, time-sorted, monthly satellite files as daily files are delivered each day. The monthly files contain data for the specific month and satellite; therefore users can easily retrieve data for a particular time span.

The CDDIS staff continued to migrate older SLR full-rate data from magnetic tape to on-line. Monthly files of full-rate data are created from the daily station files approximately six months after the observation month.

The CDDIS continued to support the ILRS Analysis Working Group (AWG) pilot projects by archiving solutions from ILRS Analysis Centers (ACs) and Associate Analysis Centers (AACs). These solutions were deposited in the CDDIS by the ACs and AACs and copied to public disk areas within the SLR data directories.

The file of SLR eccentricity information was modified in 2001. The new format accommodates large eccentricity values amounting up to several kilometers, includes the Cartesian eccentricities corresponding to the local vectors, and includes all known DOMES numbers for the SLR sites.

SUPPORT OF THE ILRS CENTRAL BUREAU

The CDDIS staff continued to maintain the e-mail distribution lists (or exploders) to aid communication within the ILRS infrastructure. A list of these exploders and their members can be viewed at URL:

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

These e-mail exploders are maintained in an automated fashion, updated when any changes are made to the data base of personnel information.

The CDDIS computer facility hosts the Web site for the ILRS:

http://ilrs.gsfc.nasa.gov

The CDDIS staff also assisted the ILRS Central Bureau in preparation and publication of the 2000 ILRS Annual Report.

KEY POINT OF CONTACT

Ms. Carey E. Noll	Phone:	(301) 614-6542
Manager, CDDIS	Fax:	(301) 614-5970
Code 920.1	E-mail:	noll@cddis.gsfc.nasa.gov
NASA GSFC	WWW:	http://cddisa.gsfc.nasa.gov/cddis_welcome.html
Greenbelt, MD 20771		
USA		

6.2 EDC 2001 GLOBAL DATA CENTER REPORT

Wolfgang H. Seem ller, *Deutsches Geod tisches Forschungsinstitut (DGFI)*

INTRODUCTION

Since November 1998 the EDC serves as one of the two ILRS Global Data Centers. All SLR data and information continue to be available to the public via our ftp server and/or at the Web server of DGFI at the addresses mentioned at the end.

The EDC hardware components reported in the ILRS Annual Report 2000 have not changed.

DEVELOPMENTS IN 2001

The maintenance and monitoring of the SLRmail and SLReport mail exploder for communication within the ILRS was performed, and some minor errors were eliminated. The same was done for the backup procedures for time bias functions and predictions. The SLR station change and configuration log files were also updated when the stations sent their changes in the appropriate way.

The hourly NP data exchange procedure was updated several times, and is well established now. All data files at our ftp server are updated hourly, and additionally the corresponding summary files are updated too. The hourly updated files are available at the ftp server in the directories:

pub/laser/qldata/satname (e.g.satname lageos1)

and the hourly updated summary files in:
pub/laser/summaries/sum_yymmdd.edc
sum_yymmdd.htsi
sum_yymmdd.global
where: *yy is the year, mm is the month, and dd the day of the month*.

The hourly transferred NP files from EDC, CDDIS/HTSI, and the summaries of both are available at:

pub/laser/qldata/hourly	(for EDC)
hourly_htsi	(for CDDIS/HTSI)
hourly_global	(for both)

The same was done for the daily and subdaily predictions. The procedures were updated due to new requests and/or new satellites. Predictions are stored at:

pub/laser/predictions	(predictions of HTSI)
pub/laser/predictions/DPAF-PRED	(predictions of ERS-2 from D-PAF/GFZ)
RGO_PRED	(predictions of RGO/NERC)
CHAMP_PRED	(predictions of CHAMP from D_PAF/GFZ)
GRACE_PRED	(predictions of GRACE from D_PAF/GFZ)
MCC_PRED	(predictions of MCC/Moscow)
NASDA_PRED	(predictions of NASDA/Japan)

Backup procedures for routine operations are in place if the primary responsible institutions are not available.

FUTURE PLANS

Procedures need to be extended to handle two-color NP SLR data files. A quality check of all incoming NP files has to be executed before delivery to CDDIS/HTSI, and the SLR stations should be informed about blunders in their data for resubmission of these incorrect data.

Furthermore, the procedures for controlling the data contents at both ILRS global data centers have to be updated to guarantee the same content at both sites. Most of EDC s effort comes from new requests and new satellite projects.

REFERENCES

Seemueller, W., EDC Report, In: Pearlman, M., Taggert, L. (eds.), International Laser Ranging Service 1999 Annual Report, pp. 148-150, NASA/TP-2000-209969, 2000.

Seemueller, W., EDC Report, In: Pearlman, M., Taggert, L., and Torrence, M. (eds.), International Laser Ranging Service 2000 Annual Report, pp. 6-7 to 6-8, NASA/TP-2001-209987, 2001.

See also reports at former CSTG SLR/LLR Subcommission and ILRS General Meeting reports at the ILRS Web pages.

KEY POINTS OF CONTACT

Contact person for EDC:

Wolfgang Seem ller
DGFI
Marstallplatz 8
D-80539 Muenchen
Germany
Telephone: +49/089/23031109
Fax: +49/089/23031240
E-mail: seemueller@dgfi.bdaw-muenchen.de

e-mail exploders:

edc@dgfi.badw-muenchen.de

slrmail@dgfi.badw-muenchen.de

slreport@dgfi.badw-muenchen.de

slrtbf@dgfi.badw-muenchen.de

EDC Web Page http://www.dgfi.badw-muenchen.de/edc/edc.html

anonFTP ftp.dgfi.badw-muenchen.de (anonymous)

ILRS Web Pages (mirror of ILRS Web pages at CDDIS):

http://www.dgfi.badw-muenchen.de/edc/ilrs/ilrs.gsfc.nasa.gov/ilrs_home.html

Section 7

Analysis Center Reports

SECTION 7 - ANALYSIS CENTER REPORTS

7.1 SATELLITE LASER RANGING

7.1.1.0 ANALYSIS CENTERS INTRODUCTION

Peter Dunn, *Raytheon ITSS*

The Analysis Centers continuously refine their techniques for processing information from the Data Centers and regularly make the results of their analysis available to ILRS participants. The Centers deliver standard products to the Global Data Centers and to the IERS, among other recipients, and provide a level of quality assurance on the global data set by monitoring individual station performance via the fitted orbits used in generating the quick-look science results. The interval and time lag for product delivery specified by the Governing Board determines the credential as Analysis or Associate Analysis Center, and three institutions currently qualify as Analysis Centers.

CSR at the University of Texas has now completed the preparation of a new system based upon the ITRF2000 terrestrial reference frame on which to base their weekly analysis of LAGEOS-1 and LAGEOS-2. This information is also accessible, together with CSR 3-day EOP values via the web and anonymous ftp. They will continue to provide the CSR9501 system EOP values which NASA uses for the operational orbit determination for TOPEX/Poseidon. CSR also provides evaluation and technical support of new systems in engineering status and supports the determination of the ITRF through the submission of annual SLR tracking station position and velocity solutions. Delft University of Technology s QLDAC also provides a semi real-time quality control of observations on LAGEOS-1, LAGEOS-2 and ERS-2, and reports to the stations on a regular basis to assist in monitoring the performance of operational systems, as well as for technical support of systems in engineering status. QLDAC also produces accurate EOPs for inclusion in the USNO/IERS bulletins, and provides information for scientific interpretation and for the motivation of data analysis. Moscow s MCC provides regular daily values of polar motion and length-of-day, and adds GLONASS analysis to its bulletins of LAGEOS-1 and LAGEOS-2 SLR station data performance, as well as producing precise orbits for GLONASS and Westpac orbits and other low satellites.

Associate Analysis Centers provide a variety of capabilities to supplement the products of the main Analysis Centers. During 2001, SLR data analysis activities at the ASI Space Geodesy Center "G. Colombo" (CGS) have continued to study tectonic plate motion, Earth rotation and polar motion, time variations of the Earth s gravitational field and satellite orbit determination. The realization of reference frames and the combination of geodetic solutions represented the primary interest of the analysis. The study of satellite rotation, in particular, by spectral analysis of the MLRO full rate data, has produced estimates of LAGEOS-2 rotation period and slow-down rate. The CODE group at the Astronomical Institute of the University of Berne has set up the SLR-GPS Quick-look Service to monitor the SLR observations using IGS rapid and final orbits. These are available soon after the end of the observation day and thus can provide rapid feedback on the quality of the SLR observations.

The Central Laboratory of Geodesy (CLG) at the Bulgarian Academy of has developed a satellite orbit determination and parameter estimation software (SLRP). The Center employs the processor to provide global geodetic SLR solutions to the IERS and ITRF section of the IGN. Information about the CLG and the SLR analysis activity will be soon available on the web-server under construction in the Laboratory. CRL has developed the orbit analysis software package CONCERTO written in Java, which was used to conduct most of their 2001 activities. The Center has continuously been involved in the SSC/EOP pilot projects driven by the ILRS Analysis WG. Future plans include an extension of their satellite signature studies to derive systematic dependence of the center-of-mass corrections of spherical geodetic satellites.

The DGFI in Munich employs the software package DOGS (DGFI Orbit and Geodetic Parameter Estimation Software) for routinely high precision processing of SLR tracking data for station coordinates, EOP's and geopotential coefficients. They plan to extend routine processing and analysis to other satellites, such as Ajisai and Starlette in the future. The Russian Academy of Science s IAA Associate Analysis Center continues to regularly submit EOP operational and final solutions to the IERS. Global fitting of the LLR observations have also been analyzed to determine corrections to UT0 and verify whether LLR is a viable component of EOP monitoring. The NASDA Associate Analysis Center has been routinely processing Ajisai, LAGEOS-1, LAGEOS-2 and LRE data for precise orbit determination, station coordinates, Earth orientation parameters and SLR station performance monitoring for some time. Plans are underway to establish a procedure for ADEOS-II in routine operation and preparation for ADEOS-II launch operation. In Grasse, CERGA s data analysis of LAGEOS observations, permanent GPS receiver measurements, and absolute gravimetry measurements has led to improvements in orbitography and positioning quality control. In particular, this analysis has conducted an accurate calibration of the French Transportable Laser ranging station as well as the Grasse Lunar Laser Ranging station.

The Norwegian Defence Research Establishment s FFI, which is also an IVS Analysis Center, offers the capability to combine VLBI, GPS, and SLR data at the observation level, and continuously improves the GEOSAT software used for the analysis. The group at JCET/GSFC in Greenbelt, Maryland continues to generate weekly solutions as a contribution to the IERS/ITRF Pilot Project for monitoring the episodic and seasonal variations in the definition of the geocenter, and is also generating weekly SINEX following ILRS-adopted standards. The Department of Geomatics at Newcastle University has been active in space geodetic research for over a decade. Their current ILRS activities include precise orbit determination of altimetric and geodetic satellites utilizing SLR, DORIS, PRARE and altimetry in the form of single and dual satellite crossovers. Their combination solution approach for GPS and SLR coordinates is being extended to Earth rotation parameters. The Geoscience Australia Associate Analysis Centre has been routinely processing LAGEOS-1 and LAGEOS-2 data for satellite orbit determination, station coordinates, Earth Orientation Parameters and SLR station performance monitoring. In addition, on an opportunity or project basis, Stella, Starlette and Etalon data is also processed.

The automatic service at the NERC SLR facility at Herstmonceux and Monks Wood, UK was considerably upgraded during the year, to include more satellites and short-arc analyses for the whole Network. Their work suggests that an improvement in the quality of the precise orbits of the GLONASS satellites in particular could be achieved by incorporating SLR data into their derivation. The central task of the BKG geodetic division is to provide and update the Geodetic Reference Networks of the Federal Republic of Germany, and continues to participate in the ILRS pilot projects. Satellite orbits, station position and velocities, EOP solutions, geo-centre and GM variations are produced on a regular basis to contribute to the IERS and other services.

In 2001, the GeoForschungsZentrum (GFZ) Potsdam continued its ILRS activities of the previous years. The main focus was again on the routine provision of high quality predictions for the ERS-2 and CHAMP satellites. The launch of the GRACE satellite in 2002 will add two new satellites to the prediction work, and will allow a much more precise determination of the gravity field of the Earth. The Navigation Support Office of the European Space Operation Centre (ESOC) provides high-precision orbit data for ESA s Earth observation missions, such as ERS-1, ERS-2 and the future ENVISAT mission (launched March 1, 2002). Future plans include the processing of data for all current and future ESA satellites equipped with a LRR array (e.g. CryoSat, GOCE), and in test mode for a number of non-ESA LEO missions, such as Jason.

7.1.1.1 CENTER FOR SPACE RESEARCH (UT/CSR)

Richard J. Eanes, John C. Ries, Minkang Cheng, *University of Texas Center for Space Research*

CURRENT ACTIVITIES

Weekly EOP estimation and SLR Network Quality Control

Although our routine weekly analysis of LAGEOS-1 and LAGEOS-2 continues to use the CSR95L01 system of models and station positions for EOP estimation and SLR residual analysis, we have now completed the preparation of a new system based upon the ITRF2000 terrestrial reference frame. The improved station positions and models of the new system allow significant improvements in the quality of the resulting EOP and in our ability to detect small systematic errors in the ILRS normal points. We will soon begin to report results using the new system while continuing to provide 9501 system EOP to the TOPEX/Poseidon POD team during a short transition period.

As we developed plans for the new CSR system, the ILRS network successfully implemented an hourly distribution cycle for ILRS range normal points. This success convinced us that automation of the new system was feasible and that the improved timeliness of the hourly LAGEOS normal points might once again allow a significant contribution of SLR to the IERS rapid service product, Bulletin-A. Achieving this goal is difficult due to the high quality and timeliness of the IGS Rapid Service product and its automated use by USNO to compute daily EOP estimates and predictions. Based on successful tests of the new procedures made during the last two months, we are confident that the benefits of automation have justified the required effort and will soon begin daily distribution of EOP results in the new system

The automation is accomplished via sequences of Unix shell scripts activated using the Unix cron utility. First we download the most recent two days of hourly ILRS NP files from both the CDDIS and GFZ data centers. The hourly files are then supplemented with the daily files created at both ILRS data centers in order to minimize the chance of missing any data. When the update of our normal point archive is completed the main analysis script begins the required orbit computations. For our initial tests the analysis script was configured to process the data for three pairs of SLR targets (LAGEOS-1/2, TOPEX/Jason-1, and GRACE-1/2) at six hour intervals. If the need arises the procedure can be easily be extended to include other satellites. We believe that increased use of multiple targets will be one of the most productive ways to extend the set of useful ILRS products. A relevant example is the combined use of SLR data and GRACE data to obtain improved results for the variations of low degree gravitational coefficients (n=2,3,4). This will also allow the GRACE results to be tied in to the much longer record that SLR techniques have provided.

Using the CSR95L01 models, the weighted RMS of range residuals computed in 3-day arcs has typically been 15-25 mm in the last several years. Comparable fits in the new system are now between 6 and 12 mm as shown in Figure 7.1.1.2-1. Figure 7.1.1.2-2 illustrates one of the benefits of the improved system by documenting the detection of a small error in the time-tags of normal points from the Graz observed during a four-day span in early 2000. To our knowledge this problem has not been previously reported even though its impact (if not corrected) on our EOP product is easily noticed. Graz observations of LAGEOS-1 and LAGEOS-2 are given the largest possible weight in our analysis because of their abundance, regularity and high quality (Graz is, in our opinion, the SLR system least likely to have a problem). Sub-decimeter level problems at key stations can sometimes be quite difficult to distinguish after orbital and geodetic parameters are adjusted, hence any improved problem detection capability is valued.

The LAGEOS-1 spin-rate is now quite small, and large variations in the orientation of the spacecraft s spin axis are now common. As a result, modeling the LAGEOS-1 orbit at the sub-centimeter level is becoming increasingly more difficult. In fact, the short duration of nearly 20 mm RMS of LAGEOS-1 residuals (but not LAGEOS-2) evident in Figure 7.1.1.2-1 is due a 10 to 100-fold increase in the size of the average along-track acceleration which we routinely adjust every three days. This latest LAGEOS-1 acceleration anomaly only lasts a few days centered on April 05, 2002 just before the peak of the eclipse period. It is likely that this type of event occurs when the LAGEOS-1 spin axis and the Sun are aligned in a way that maximizes the size of the resulting thermal forces and fails to average down over each orbit. In response, we now estimate daily along-track acceleration corrections for LAGEOS-1. This unfortunate situation will probably only get worse and may soon require the development of a better parameterization of anomalous spacecraft accelerations.

The LAGEOS-1/2 near-real-time daily EOP solutions are easily better than the 3-day LAGEOS-1 (95L01) series we currently provide. The RMS difference between the new series and the IGS Rapid series is 0.2 mas for polar motion and 40 microsec for LOD which is comparable to the excellent operational series provided by IAA. For comparison, the RMS difference between IGS Rapid and Bulletin-A is below 0.1 mas for polar motion and 30 microsec for LOD. We preliminarily conclude that use of our new series will probably not significantly improve the excellent Bulletin-A polar motion result. On the other hand, we believe that the last few LOD estimates will help to improve the determination of the current trend in the UT1 error of the previous prediction. Many figures showing results obtained in tests of our new procedures can be downloaded via anonymous ftp from:

ftp.csr.utexas.edu in pub/slr/newops_gallery

Precision Orbit Determination and Verification

SLR and DORIS tracking provide the principal means of precise orbit determination for the T/P altimeter spacecraft, supporting an orbit accuracy of approximately 2 cm in the radial direction. Studies have demonstrated that the SLR data contribute critically to the accuracy of the centering of the altimeter orbits with respect to the Earth s mass center, particularly along the Z-axis (along the Earth s spin axis). This centering is critical to avoid artificial signals in the observed sea surface variations between the hemispheres that might be erroneously interpreted. The SLR data, due to the absolute ranging information that they provide, help to center the orbit more precisely and consistently, as well as contribute to the overall orbit accuracy. They also provide an unambiguous determination of the height of the spacecraft above a tracking station, particularly for passes which cross at a high elevation angle. This capability is unique to SLR, and it is crucial for orbit accuracy assessment at the current levels. We continue to exploit this capability for Jason-1 orbit verification, and this will be extended to ENVISAT orbit studies.

Terrestrial Reference Frame

We have continued to participate in the Analysis Working Group s POS+EOP pilot project devoted to improving the quality of SLR results related to the evolution of the terrestrial reference frame. In addition to providing the required sequences of SINEX files for use in comparisons with other the other analysis centers we have computed a series of monthly results going back to the LAGEOS-2 launch in late 1992. Figure 7.1.1.2-3 shows the Z-translation component of the Helmert transformation that best fits the differences between the monthly CSR solution and ITRF2000. The comparison suggests that the ITRF origin may be different from the actual center of mass by a small (~4 mm @ 1997.0) offset plus a trend of approximately 1 mm/y. Including more recent data increases the apparent drift to 1.4 mm/yr. Discrimination between step changes and a slow trend is, however, quite difficult. Either way, we conclude that fixing ILRS station positions to ITRF2000 (with no geocenter adjustment) will result in a terrestrial frame realization that differs from observational constraints by more than 1 cm in Z at the beginning of 2002. This highlights the continued importance of SLR in the maintenance of ITRF. By comparison, the differences in X and Y are only 0.2-0.3 mm/yr. The annual cycle in the Z-geocenter time series shown in Figure 3 is (on average) about 4 mm which is about the size expected due to seasonal mass redistribution between the Northern and Southern hemisphere.

Additional EOP and station position results can be found in the AWG pages of the ILRS Web site and at:

ftp.csr.utexas.edu in pub/slr/pos+eop

and other nearby directories.

FUTURE PLANS

We will strive to continue improvements in the automation of our SLR analysis applied to rapid-service EOP determination and network quality control. Increasing use of multi-satellite SLR analysis for monitoring the drifts in ITRF2000, temporal variations of low-degree geopotential harmonics and POD for altimetric satellite orbits is anticipated in the next year.

Analysis Working Group Members

Richard Eanes, Minkang Cheng, John Ries, Bob Schutz

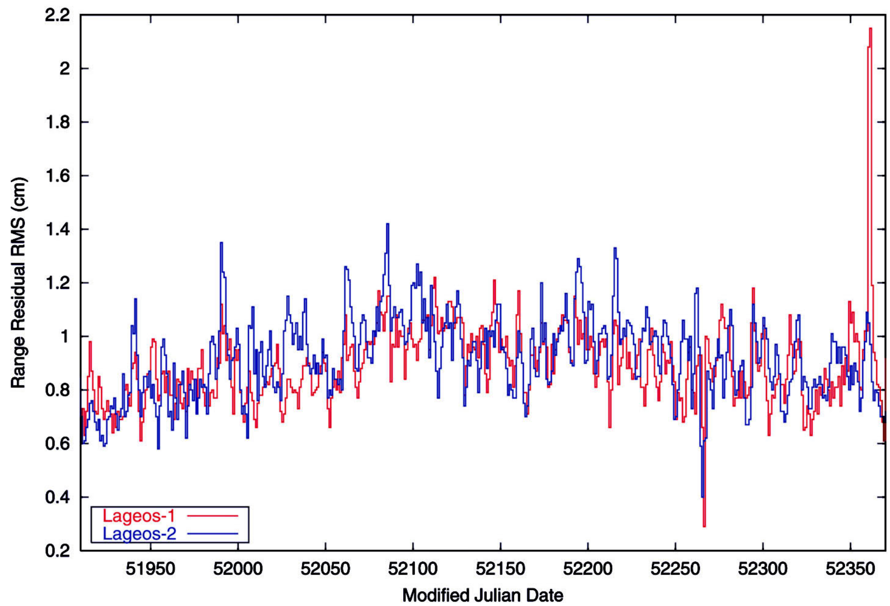


Figure 7.1.1.2-1. Typical range residual RMS for 3-day arcs from LAGEOS-1 and LAGEOS-2

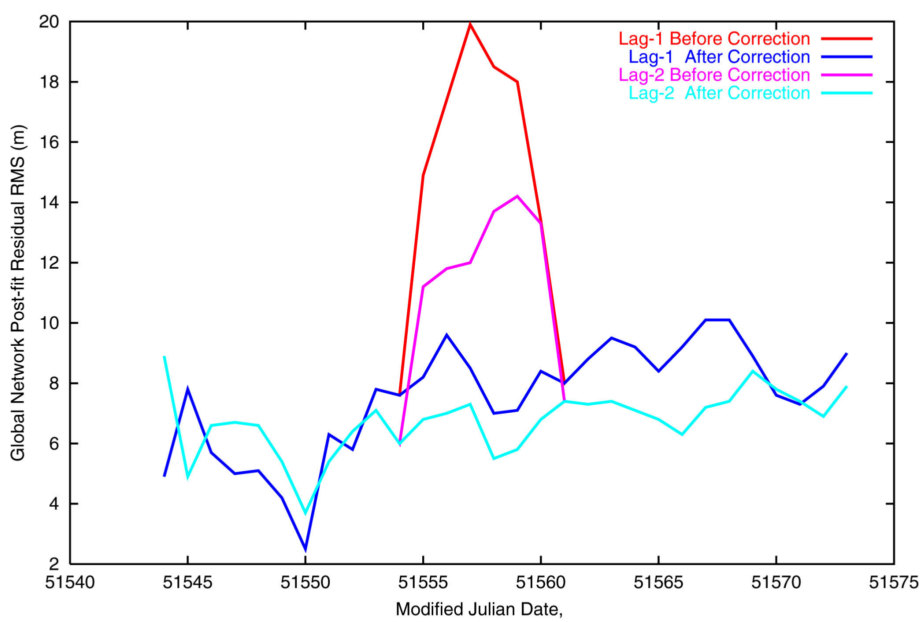


Figure 7.1.1.2-2. Effect of ~25 microsecond Graz time bias during 14-18 January 2000

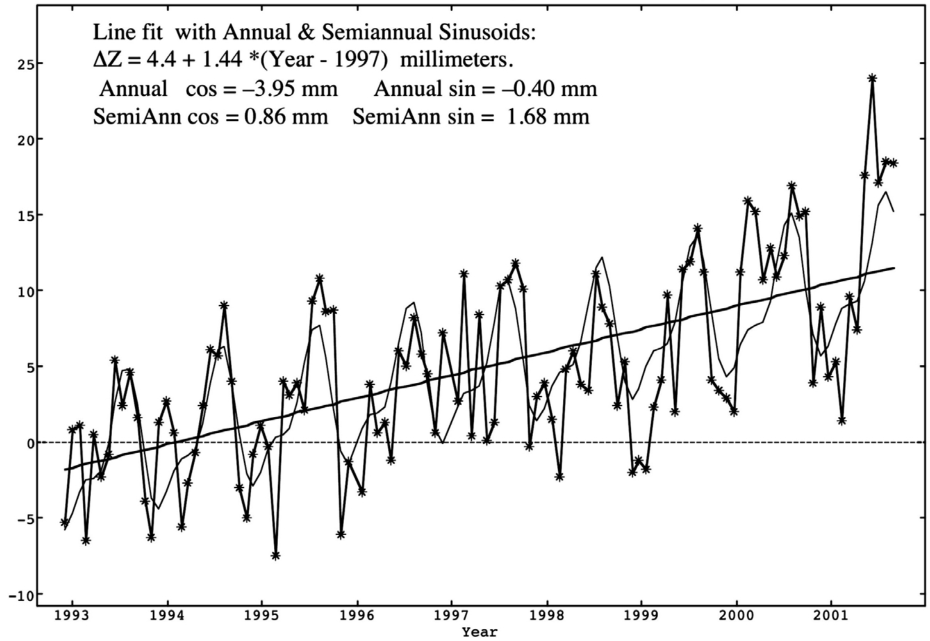


Figure 7.1.1.2-3. Z-translation which moves ITRF2000 toward CSR SLR monthly solutions.

REFERENCES

Cheng, M. K., Time-varying Earth's Gravity Field from Analysis of SLR data, presented at 12th International workshop on Laser Ranging, Matera, Italy, 13-17 November, 2000.

Cheng, M. K., Secular Variations in the Earth's Gravity Field and its Geoscience Application, presented at Fourth Workshop on Asia-Pacific Space Geodynamics Program, Shanghai, China, 14-19 May, 2001.

Eanes, R. J., and J. C. Ries, Monthly and Constant Velocity Station Positions from LAGEOS and TOPEX/POSEIDON, presented at ITRF2000 Workshop, Paris, France, November 2-3, 2000.

Eanes, R. J., and J. C. Ries, CSR SLR Contribution to ITRF2000, presented at ITRF2000 Workshop, Paris, France, November 2-3, 2000.

Eanes, R. J., and J. C. Ries, Supporting Role of Laser Ranging for Satellites Tracked by Microwave Techniques, presented at EGS XXVI General Assembly, Nice, France, March 26-30, 2001.

Eanes, R. J., Sources of Systematic Errors in Reference Frame Determination by SLR, presented at EGS XXVI General Assembly, Nice, France, March 26-30, 2001.

Nerem, R. S., R. J. Eanes, J. C. Ries, and G. T. Mitchum, The Use of a Precise Reference Frame in Sea Level Change Studies, in Towards an Integrated Global Geodetic Observing System (IGGOS), R. Rummel, H. Drewes, W. Bosch, and H. Hornik, editors, Springer-Verlag, 8-12, 2000.

7.1.1.2 DELFT UNIVERSITY OF TECHNOLOGY

Eelco Doornbos, Ron Noomen, Remko Scharroo, *The Delft Institute for Earth-Oriented Space Research*

INTRODUCTION

The Delft Institute for Earth-Oriented Space Research (DEOS) at Delft University of Technology (DUT) has been active in the field of SLR analysis since about 1980. The current activities include (i) the LAGEOS quick-look analysis, (ii) LAGEOS crustal dynamics investigations, and (iii) ERS-2 orbit computations.

LAGEOS QUICK-LOOK ANALYSIS

The Quick-Look Data Analysis Center (QLDAC) has been operational at DUT/DEOS since the beginning of 1986. The main objectives are a semi real-time quality control of the global SLR observations on LAGEOS-1 and LAGEOS-2, and the production of Earth Orientation Parameters (EOPs), for inclusion in the IERS Bulletins A.

Being an operational analysis service, the QLDAC analysis system has run all through the year 2001. QLDAC benefitted from the reorganisation and automation of the analysis system, which took place at the end of 2000 and at the beginning of 2001: the old, menu-driven system was succeeded by a simpler and fully autonomous analysis system. For continuity reasons, the computation model basically follows the IERS 1996 Standards. Typically, an rms-of-fit of 33 mm on average was obtained for the 10-day arcs during 2001. As for the (near) future, QLDAC intends to introduce new elements in the operational analysis: (1) the use of internet to disseminate analysis results, (2) the replacement of the rather old model for station coordinates SSC(DUT)93L05 by ITRF2000, (3) the inclusion of models for ocean ands atmospheric pressure loading, (4) the addition of other satellites, probably the Etalons, and (5) the increase of the frequency of the analysis.

CRUSTAL DYNAMICS

The SLR observations on LAGEOS-1/2 are also used for crustal dynamics investigations. Here, it is extremely important to model the orbit of the LAGEOS spacecraft as well as possible. An element of the dynamic model for these vehicles which has gained significance during the last few years is the thermal forces (the pressure force exerted by the photons emitted by the hot components of the satellite surface). Since the rotation of LAGEOS-1 has almost stopped, these forces do no longer average out, and the result can easily deteriorate the quality of orbit solutions. DEOS has developed the preliminary LAGEOS Spin Axis Model (LOSSAM-1), which is based on (a development of) the theory on rotational dynamics available in literature and independent observations of the spin axis orientation and the spin rate coming from various data sources. To illustrate LOSSAM-1: the agreement between the spin-axis orientation observations and their model equivalents for LAGEOS-2 is about 0.4 degree.

ERS-2 NEAR REAL-TIME AND PRECISE ORBIT DETERMINATION

DEOS has been involved in the analysis of orbits and altimetry of the European remote sensing satellites ERS-1, ERS-2 and ENVISAT, since well before the launch of ERS-1 in 1991. In the routine orbit determination for ERS-2, SLR measurements are combined with altimeter heights and crossovers. This is done in order to compensate for non-gravitational force model errors with a parameterization of drag scale factors and empirical 1-cpr accelerations, which is not possible using SLR tracking alone. The orbits are computed at four distinct times with an increasing level of accuracy, in synchronization with the incoming altimeter data.

In an automatic process, near real-time altimetry is used together with SLR data to generate orbits for the entire previous day. These orbits are included in the NOAA ERS-2 RGDR altimeter product at approximately 9:20 UTC daily. The first human intervention takes place in the editing of SLR residuals for the production of the so-called fast delivery orbits, every Tuesday and Friday afternoon. These orbits are computed in arcs of 5.5 days and form the basis for the preliminary and precise orbits. These are identical to the fast-delivery orbits, except for the inclusion of the preliminary and final altimetry data from ESA s OPR products. Since these products have a lag-time of about one month and three months, respectively, the resulting orbits also benefit from any corrections to the geophysical quantities (EOPs and solar/geomagnetic indices) and updates in the SLR data.

The radial accuracy of the DEOS orbits for ERS-2 has been estimated at approximately 10 cm for the near real-time orbits to 5 cm for the precise orbits. In 2001 it has not always been possible to reach the highest level of orbit accuracy. This is due mainly to the high solar-activity levels, which have made atmospheric drag forces large and unpredictable at times. In addition, the failure of several gyros onboard the spacecraft have forced ESA engineers to devise a new method for attitude determination, which had to be calibrated. During these periods, the satellite has shown deviations from its nominal attitude, which has a negative influence on the surface force model accuracy, as well as on the altimeter data that is used in the orbit determination. DEOS continues to investigate possible further improvements in the orbit determination accuracy of ERS-2.

Also, in 2001, DEOS has been heavily involved in preparations for the processing of SLR, DORIS and altimeter observations of ENVISAT, which was launched on March 1, 2002. These preparations include, amongst others, the development of a state-of-the-art model for surface forces affecting spacecraft dynamics.

The ERS-2 orbits of course are used for scientific investigations (sea-level variations, ice cap elevation changes), but this is beyond the scope of this report.

7.1.1.3 MISSION CONTROL CENTER (MCC) ANALYSIS CENTER

Vladimir Glotov, *Russian Mission Control Center*

INTRODUCTION

The SLR data Analysis Center is a part of the MCC Navigation and Coordinate-time Service. MCC has certain technical capabilities and its own software for the precise data processing (Figure 7.1.1.3-1).

FACILITIES/SYSTEMS

There are three branches of our software used for routine service by the MCC Analysis Center. The first is STARK, initially prepared as general software for usual missions with high accuracy. The other software, POLAR, is much more complicated and used for determination of highly accurate orbits, Earth Orientation Parameters (EOP), station coordinates and performance, etc. The new software STARK-AUTO&STARK-SYSTEM were written combining DEC FORTRAN and C++ Builder and directed toward automation of the operations and different kind of the precise tracking data (SLR, "phases" and code navigation GPS/GLONASS data etc.) processing. All software packages run on standard IBM compatible Pentium computers. Special calculation methodology allows reduced computation time without loosing accuracy. So, even though the software is suited for the PC, it imposes no limitations on precise data processing.

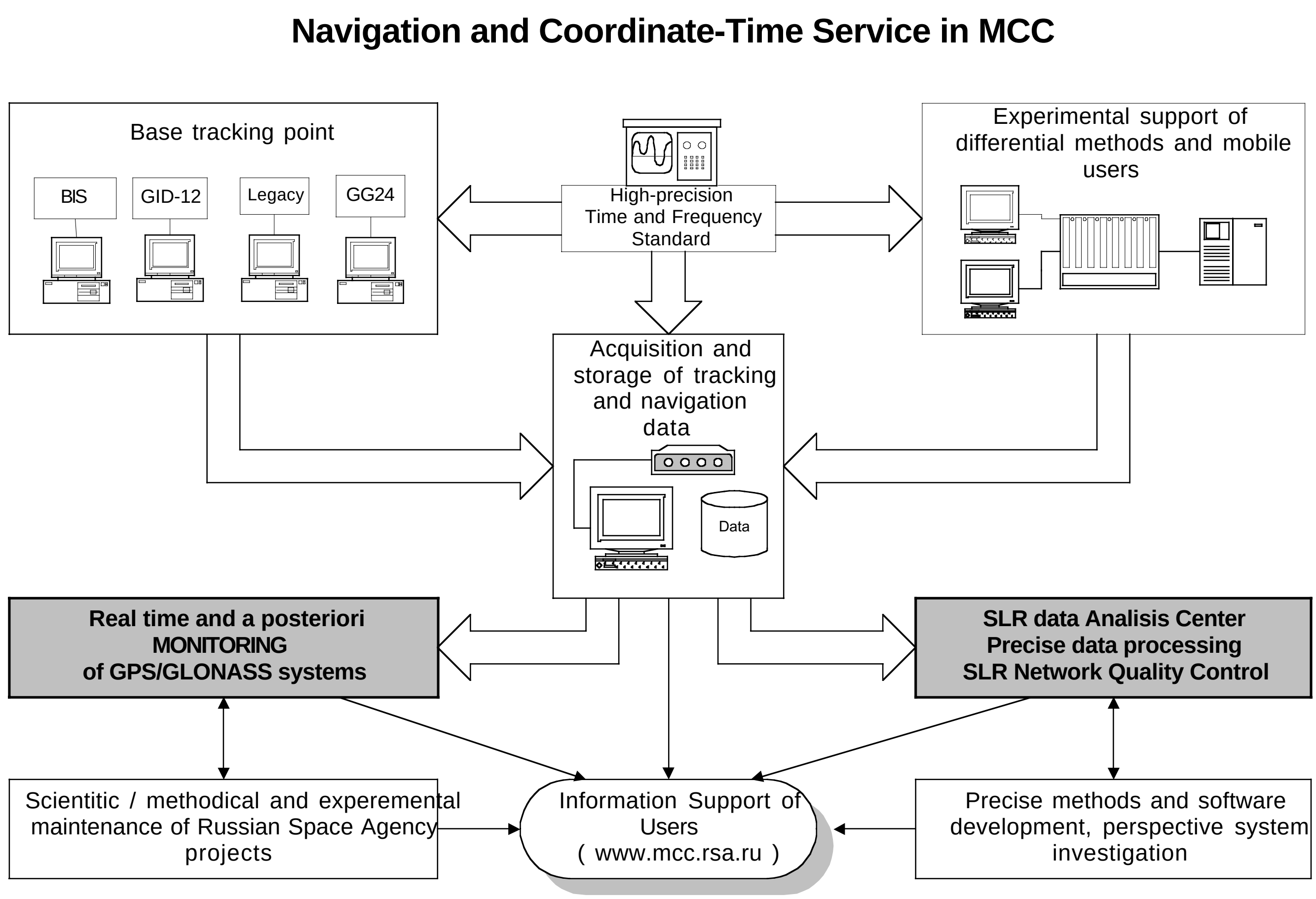


Figure 7.1.1.3-1. Technical capabilities and MCC activities related to the precise navigation issues

Current Activities

In 1993, MCC started routine determination of Earth Orientation Parameters (EOP) in cooperation with IERS. Based on the LAGEOS satellites SLR data, EOP are sent weekly to the Central (Paris) and Rapid (Washington) IERS Bureaus. EOP accuracy has been improved to the level of a few millimeters. Plots are available at

http://maia.usno.navy.mil/plots.html

In 1996 MCC started a regular service of assessing SLR stations performance. All the data of LAGEOS-1 and -2 has been analyzed to get values of time and range biases and RMS. The routine service requires two levels of data filtering: automatically exclude outliers and wrong sessions and manually check and correct results.

Since 1995, the MCC has permanently supported orbit determination of GLONASS satellites based on SLR data. For this work, a GLONASS solar pressure model was developed. Orbits for GLONASS satellites (in SP3 format) are regularly sent to the CDDIS for the determination of the final orbits based mainly on the "phase" GLONASS data. Due to limited number of measurements, MCC currently determines eight day GLONASS orbits with SLR data with four day time offset between the solutions. The central four middle days from each arc are then used for the generation of the SP3 formatted orbits.

Key Points of Contact

Coordinator of the work	Vladimir Glotov	cnss@mcc.rsa.ru
Main expert and person responsible	Vladimir Mitrikas	cnss@mcc.rsa.ru
Administration support	Sergey Revnivych	cnss@mcc.rsa.ru

7.1.2 ASSOCIATE ANALYSIS CENTERS:

7.1.2.1 ASI/CGS ASSOCIATE ANALYSIS CENTER FOR ILRS

G. Bianco, R. Devoti, V. Luceri, P. Rutigliano, C. Sciarretta, *Agenzia Spaziale Italiana*

INTRODUCTION

During 2001, SLR data analysis activities at the ASI Space Geodesy Center "G. Colombo" (CGS) have been directed, as in the past, to the study of tectonic plate motion, Earth rotation and polar motion, time variations of the Earth s gravitational field and satellite orbit determination. The realization of reference frames and the combination of geodetic solutions represented the primary interest of the analysis.

Information on the CGS and some of the analysis results are available at the CGS WWW server GeoDAF (Geodetical Data Archive Facility):

http://geoday.mt.as.it

CURRENT ACTIVITIES

- International Terrestrial Reference System (ITRS) maintenance: the production of IERS oriented products (global SSC/SSV and EOP time series) is regularly performed to assure the CGS contribution to the reference frames establishment.
- ILRS AWG Pilot project: submission of coordinate/EOP solutions following the pilot projects requirements and comparison/combination of the submitted solutions.
- Satellite rotation: the spectral analysis of the MLRO full rate data, over a 3 year time span, produced estimates of LAGEOS-2 rotation period and slow-down rate, now available to the scientific community.
- ¥ Geodetic solution combination: the combination algorithms are defined with the aim to build a unique SSC/SSV solution for the Mediterranean area, taking into account all the available solutions from different analysis groups.

DATA PRODUCTS PROVIDED

- Coordinates and velocity fields (SSC/SSV) of the global SLR tracking network, from LAGEOS-1 and -2 data, submitted to IERS for the ITRF2000 frame realization
- Long series (1984-2000) of Earth Orientation Parameters (EOP), from LAGEOS-1 and -2 data, submitted to IERS for the 2000 Annual Report;
- 1-day estimated EOP, from LAGEOS-1 and -2 data, routinely provided to IERS for the monthly Bulletin˚B;
- Solution of SSC and EOP time series, estimated using LAGEOS-1 and -2 data, for the ILRS AWG pilot project on coordinate and EOP combination;
- Solution of SSC and EOP time series, estimated using LAGEOS-1 and -2 and Etalon-1 and -2 data, for the ILRS AWG pilot project following the ILRS Etalon campaign;
- Combined solution of SSC and EOP time series, estimated by different analysis centers, for the ILRS AWG pilot project on coordinate and EOP combination;
- Estimation of tectonic movements and strain-rates in the Mediterranean area combining SLR, GPS and VLBI results obtained at CGS;
- Time series of LAGEOS-2 rotational periods computed from MLRO data.

FUTURE PLANS

- ILRS AWG: investigation on the use of Etalon data for EOP, GM, gravity and participation to its new pilot project on "benchmarking and orbits" for comparison of the different analysis software.
- IERS Combination Research Centers: participation to the "IERS ERP alignment campaign" through submission of SLR solutions and comparison of submitted solutions. A large involvement in all the CRC activities is planned.
- A revised solution of geopotential zonal drifts will be implemented with updated data set and a new analysis strategy.
- CHAMP orbit determination: in response to the CHAMP AO, the CGS submitted a proposal, including orbit determination with SLR, that was accepted by the CHAMP Science Board
- Satellite rotation: further investigations on LAGEOS rotation with the use of the MLRO streak camera and new analysis methods on the ranging data LLR data analysis activities will soon start together with the MLRO lunar tracking.

MOST RECENT PUBLICATIONS

B. Bianco, M. Chersich, R. Devoti, V. Luceri, M. Selden, Measurements of LAGEOS-2 rotation by Satellite Laser Ranging observations, Geophys. Res. Lett., 28(10) (2001), 2113-2116

R. Sabadini, G. Di Donato, L.L.A. Vermeersen, R. Devoti, V. Luceri, G. Bianco, Ice mass loss in Antarctica and stiff lower mantle viscosity inferred from the long wavelength time dependent gravity field, , Geophys. Res. Lett., *in press.*

KEY POINTS OF CONTACT

Dr. Giuseppe Bianco
Agenzia Spaziale Italiana, ASI/CGS
P.O. Box ADP, 75100 Matera — Italy
tel: +39-0835-377209
fax: +39-0835-339005
e-mail: giuseppe.bianco@asi.it

Dr. Vincenza Luceri
Telespazio SpA, ASI/CGS
P.O. Box ADP, 75100 Matera - Italy
tel: +39-0835-377231
fax: +39-0835-334951
e-mail: cinzia.luceri@asi.it

7.1.2.2 ASTRONOMICAL INSTITUTE OF THE UNIVERSITY OF BERN (AIUB)

U. Hugentobler, H. Bock, D. Ineichen, *Astronomical Institute of the University of Bern*

CURRENT ACTIVITIES

The Center for Orbit Determination in Europe (CODE) is located at the Astronomical Institute of the University of Berne and is a joint venture of the Swiss Federal Office of Topography (L+T), Wabern, the Bundesamt f r Kartographie und Geod sie (BKG) in Frankfurt, Germany, the Institut G ographique National (IGN) in Paris, France, and the Astronomical Institute of the University of Berne (AIUB). CODE is one of the eight Analysis Centers of the International GPS Service (IGS) since the start of the IGS in June 1992. Precise orbits for the GPS satellites, orbit predictions, Earth orientation parameters, station coordinates and velocities, satellite and station clock corrections, troposphere parameters, and ionosphere models are computed and delivered every day based on the observations of the IGS network of GPS stations. In the framework of the International GLONASS Experiment (IGEX) CODE delivered precise orbits for the GLONASS satellites from January 1999 to June 2000.

As an Associate Analysis Center (AAC) of the International Laser Ranging Service, CODE provides a SLR-GPS quick-look service since December 1996. It is based on the residuals of the SLR observations taken from the two GPS satellites PRN 5 and PRN 6 with respect to the CODE IGS final and rapid orbits as computed from microwave observations. Each day the SLR observations gathered over the last six days and downloaded from CDDIS are evaluated. The last four days are analyzed using the rapid orbits and the two older days using the final orbits. Comparison between the orbits from the different IGS analysis centers regularly show an internal consistency of about 2 cm RMS (1-dim) for the CODE final orbits and 3 cm RMS for the CODE rapid orbits. The external accuracy, as confirmed by SLR observations, is of about 5 cm RMS. The SLR-GPS quick-look results, covering six days, are distributed by e-mail to the SLR Report mail exploder every day — provided that new data was available — giving rapid feedback on the quality of the SLR observations. Since day 016 of year 2002 the quick-look residuals are referred to ITRF2000. Because no GLONASS orbits based on microwave observations are currently computed at CODE the quick-look service is restricted to the two GPS satellites PRN˚5 and 6.

CODE also provides daily orbit predictions for all GPS and GLONASS satellites spanning a time interval of five days. For the GPS satellites, the predictions consist of an extrapolation of the CODE rapid orbits which are based on microwave observations spanning three days. The GLONASS predictions are based on the broadcast messages collected over four days. The predictions are usually available at noon of the day after the last observations used. They are converted from the standard IGS orbit format (SP3) to IRVs by the National Environment Research Council (NERC) and used by several of the (European) SLR tracking stations.

FUTURE PLANS

Although not currently combining SLR and microwave observations, the main interest of CODE on SLR data — the validation of orbits based on microwave observations — is unchanged. In the future, we plan to use SLR observations not only to GPS and GLONASS but also to low Earth orbiters carrying GPS receiver and SLR retroreflectors — such as CHAMP, GRACE, JASON, GOCE — for an independent verification of GPS based precise orbit determination techniques.

7.1.2.3 BUNDESAMT F R KARTOGRAPHIE UND GEOD SIE (BKG)

Bernd Richter, *Bundesamt f r Kartographie und Geod sie*

INTRODUCTION

The central task of the BKG geodetic division is to provide and update the Geodetic Reference Networks of the Federal Republic of Germany including

- Survey work (Station Wettzell, TIGA / Chile, O Higgins / Antarctica - SLR, VLBI, GPS, GLONASS observations, survey campaigns, and other activities), and theoretical work for collection and preparation of survey data, also with
- Cooperation in bilateral and multilateral activities for definition and updating of global reference systems in the framework of ILRS , IVS , IGS, IERS and
- Further development of the surveying, observation and analysis technology used as well as representation of the relevant interests of the Federal Republic of Germany on an international level.

The BKG Associate Analysis Centre processes routinely Lageos-1 and Lageos-2 data for satellite orbit determination, station co-ordinates, Earth Orientation Parameters and SLR station performance monitoring. In addition, special investigations have been made to support the ILRS WG pilot studies.

FACILITIES / SYSTEM

During 2001, the computer hardware changed, and the operating system changed from UNIX to LINUX. In addition, the in-house-network changed and a new firewall protection was installed. As a consequence, routine analysis work stopped during the transition phase, which unfortunately lasted for the entire year.

CURRENT ACTIVITIES

The BKG contributed to the ILRS Analysis Working Group pilot projects with respect to station co-ordinates and EOPs taking data from LAGEOS and Etalon.

Due to the hardware and OS changes the structure of the in-house SLR data base was reorganised as well as the related programs and scripts.

Theoretical and practical investigation were performed to study the stability of the global network. If any single network solutions are to be used for further combinations (multi-satellite techniques) it is important that the datum can be removed from the estimated covariance matrix without numerical deterioration of the network. The a priori sigmas of the station co-ordinates and EOP and the strength of these constraints have a large influence upon the solution. Mathematical tools are being developed to check the datum of SLR networks.

FUTURE ACTIVITIES

The BKG will continue to participate in the ILRS pilot projects. Satellite orbits, station position and velocities, EOP solutions, geo-centre and GM variations will be produced on a regular basis to contribute to the IERS and other services.

7.1.2.4 CENTRAL LABORATORY OF GEODESY (CLG)

Ivan Georgiev and Javor Chapanov, *Central Laboratory of Geodesy at Bulgarian Academy of Sciences*

INTRODUCTION/DATA PRODUCTS PROVIDED

The Central Laboratory of Geodesy (CLG) at the Bulgarian Academy of Sciences has involved in space geodetic research in the last 20 years. Submission of global geodetic SLR solutions — coordinates (SSC) and velocities (SSV) and Earth Orientation Parameters (EOP) to the IERS and ITRF section of the IGN are in progress from 1993. The analysis has been made by the Satellite Laser Ranging Processor (SLRP) — a satellite orbit determination and parameter estimation software package, developed at the Laboratory. Information about the CLG and the SLR analysis activity will be soon available on the web-server under construction in the Laboratory.

CLG Associate Analysis Center provided the following data products:

- Submission of a global SLR solution (station coordinates and velocities and EOP) for ITRF.
- Geogravitational parameter GM and selected set of geopotential coefficients and ocean loading parameters from LAGEOS-1 and LAGEOS-2 tracking data.
- Low degree zonal rates from the analysis of LAGEOS-1 (1984-2001) and LAGEOS-2 (1993-2001).
- Global tectonic plate motion.
- Range- and time-biases for the SLR tracking stations.

CURRENT ACTIVITIES

- Reprocessing SLR tracking data of LAGEOS-1 and LAGEOS-2 with the updated and modified software version SLRP 4.0.
- Continuing to produce the IERS and ITRF oriented products — SSC, SSV and EOP.
- Research activities of the low degree zonal drifts of the geopotential, geocenter variations and SLR reference frame.
- Global tectonic motion with emphasize for the Mediterranean.

FUTURE PLANS

- Including in the analysis tracking data from the Etalon satellites.
- GPS/GLONASS orbit determination from SLR tracking data.
- Continue the SLR IERS and ITRF products submission.
- Participate in the future ILRS pilot projects.

REFERENCES

M. Pearlman, M. Torrence and L. Taggart (eds.). International Laser Ranging Service 2001 Annual Report. NASA/TP-2001-209987, 2001.

I. Georgiev, J. Chapanov. Analysis of Laser Ranging to the Geodynamic Satellites LAGEOS-1 and LAGEOS-2 for the Period 1984-2000. Accepted in Bulgarian Geophysical Journal, 2002.

J. Capanov, I. Georgiev. Secular Drift of the Low Degree Zonal Coefficients Obtained from Satellite Laser Ranging to the Geodynamic Satellites LAGEOS-1 and LAGEOS-2. Accepted in Bulgarian Geophysical Journal, 2002.

CLG Key Point of Contact

Dr. Ivan Georgiev
Central Laboratory of Geodesy
Acad. G. Bonchev Str. Bl. 1
Sofia 1113, Bulgaria
Phone: + 359 2 979 2453
Fax: + 359 2 72 08 41
E-mail: ivan@argo.bas.bg

7.1.2.5 Communications Research Laboratory

Toshimichi Otsubo, *Communications Research Laboratory*

Introduction

In August 2001, the ILRS Governing Board approved CRL as an Associate Analysis Centre (AAC) of the ILRS. This is the first AAC report from us. We have researched satellite laser ranging analysis since mid-nineties including Otsubo s two-year visit to Natural Environment Research Council (NERC) in the UK, and our research will continue as ILRS AAC activities.

CRL has developed the orbit analysis software package *concerto* written in Java, which was used to conduct most of our 2001 activities.

Current Activities

- SSC and EOP: CRL has continuously been involved in the SSC/EOP pilot projects driven by the ILRS Analysis WG. We submitted the SSC/EOP solutions to the 4th (Nice) and 5th (Toulouse) ILRS AWG pilot projects. Our 10-year SSC solution also contributed to the ITRF2000 solution released in April 2001.
- Weekly quality check: We developed an automated system to check the station quality using seven geodetic satellites (Stella, Starlette, Ajisai, LAGEOS-1, LAGEOS-2, Etalon-1 and Etalon-2. Analyzing various satellites makes it easier to find possible problems at stations. The analysis reports are being updated weekly at our ftp and Web site:

  ftp://ftp.crl.go.jp/mt/cybernetics/slrqc/ http://www.crl.go.jp/hk/slr/bias
- Satellite spin: With a continuous collaboration with NERC, we analyzed the photometer data obtained at the Herstmonceux station and estimated the spin rate and the spin axis evolution of LAGEOS-2 during 2000-2001.

Future plans

- Further development of the *concerto* software package to adapt various data types.
- Satellite signature studies to derive systematic dependence of the center-of-mass corrections of spherical geodetic satellites.

Recent Publications

T. Otsubo, H. Kunimori, K. Yoshihara and H Hashimoto, Optical response of the H2A-LRE satellite, SPIE Symposium on Remote Sensing (Toulouse), SPIE Proceedings Series 4546, 44-48, 2001.

T. Otsubo, G. M. Appleby and P. Gibbs, GLONASS laser ranging accuracy with satellite signature effect, *Surveys in Geophysics*, 22, 6, 507-514, 2001.

7.1.2.6 DEPARTMENT OF GEOMATICS, NEWCASTLE UNIVERSITY

Philip Moore, *Newcastle University*.

The Department of Geomatics has been active in space geodetic research for over a decade. Within the remit of the ILRS our current activities include:

Precise orbit determination of altimetric and geodetic satellites utilizing SLR, DORIS, PRARE and altimetry in the form of single and dual satellite crossovers. Effort is continually devoted to development of the in-house orbit determination software package *Faust*. The use of crossovers as an additional tracking type allows estimation of an extended state vector to the extent that accuracy of the lower altimeter satellites (ERS-2, GFO) is now not far short of the most precise altimeter orbit of TOPEX/Poseidon. Applications include gravity field enhancement and studies of stability of the altimetric range.

Precise orbits of LAGEOS 1 and 2 are used to determine station coordinates of the SLR tracking network. The weakly constrained solutions are use to estimate seasonal variability in the geocentre for comparison against comparable results from geophysical models. In addition to geocentre displacement the effects of loading and gravity field variations from the mass distributions have been included.

GPS pseudo-range and phase data from GPS onboard the CHAMP satellite has been used to compute orbital positioning in a reduced dynamic procedure within JPL s software suite *GIPSY-OASIS* . Overlaps provide a check on internal precision while SLR has been used as the independent check on the accuracy of orbits determined. Cartesian positioning from GPS and accelerometer data is being used to enhance the Earth s gravity field with applications aimed towards temporal variability.

The Department of Geomatics of Newcastle University is a Global Network Associate Analysis Center for the IGS producing weekly combination station coordinates for the IGS network. This rigorous approach is being applied to SLR coordinates to produce solutions superior to the individual submissions from the ILRS Analysis and Associate Analysis Centres. The combination solution approach for GPS and SLR coordinates is being extended to Earth rotation parameters.

Further information, including ERS-2 orbits are available at:

http://geomatics.ncl.ac.uk/research/research.htm

POINT OF CONTACT

P Moore
Department of Geomatics, Newcastle University
Newcastle, NE43 7RU, UK
Tel: + 44 (0)191 222 5040
email Philip.moore@ncl.ac.uk

7.1.2.7 DEUTSCHES GEOD TISCHES FORSCHUNGSINSTITUT (DGFI)

Horst M ller, Detlef Angermann, Rainer Kelm, *Deutsches Geod tisches Forschungsinstitut*

INTRODUCTION/DATA PRODUCTS PROVIDED

Since 1980 DGFI has been involved in SLR data analysis. Our software package DOGS (DGFI Orbit and Geodetic Parameter Estimation Software) is the basis for routinely high precision processing of SLR tracking data for station coordinates, EOP's and geopotential coefficients. More information on DGFI, the activities within ILRS and SLR analysis results are available at the DGFI Web-server at: http://www.dgfi.badw.de.

DGFI Associate Analysis Center provided following data products:

- Participating in the ILRS Analysis Working Group pilot projects 4 and 5A: solutions (station coordinates and EOP«s) and comparison/combination of results.
- Time series for station coordinates, terrestrial reference frame parameters (origin and scale) and J2.

CURRENT ACTIVITIES

- Reprocessing of all available LAGEOS-1 and LAGEOS-2 SLR tracking data since 1981 for a new station coordinate and velocity solution
- Researching activities related to the accuracy and long-term stability of station coordinates and velocities, SLR reference frame (origin, scale), GM, geocenter variations and EOP«s.
- Processing of Etalon SLR data.
- Combining miscellaneous station coordinate solutions as ITRF analysis center.
- Researching activity on combination of solutions from all space techniques within the scope of a ITRF combination research center.

One of our recent projects was the analysis of the long-term stability of various space techniques on the basis of weekly solutions. Figure 7.1.2.7-1 shows the weekly transformation parameters for a combined LAGEOS-1 and -2 solution with respect to ITRF2000. The translation parameters show a significant annual signal of 3 mm in X and Y and 4.5 mm in Z, but no secular motion. The scale shows a good longterm stability with a noise of below 1 ppb. This result proofs the significant contribution of SLR for the realization of a global reference frame.

FUTURE PLANS

- Continue submitting solutions within future ILRS pilot projects
- Analyze SLR data (bias parameter and station quality)
- Combine space techniques for ITRS realizations.
- Extend routine processing and analysis to other satellites (Ajisai, Starlette, etc.).
- Submit SLR products to the ILRS routinely to the ILRS (e.g. station coordinates and EOP«s on a monthly basis, multi-years solutions for station coordinates and velocities, range and time-biases for SLR tracking stations) to become an operational ILRS analysis center.

REFERENCES

D. Angermann, H. M ller, M. Gerstl, R. Kelm, W. Seem ller, M. Vei, Laserentfernungsmessugen zu LAGEOS-1 and -2 und ihr Beitrag zu globalen Referenzsystemen. Zeitschrift f r Vermessungswesen, Germany, (126) pp. 250-256, 2001.

Angermann D., K. Kaniuth, H. M ller, V. Tesmer, Contribution of Individual Space Techniques to the Realization of Vertical Reference Systems. in: Drewes, H. *et. al*, Vertical Reference Systems, IAG Symposia (124), Springer, in print, 2002.

Angermann D., H. M ller, M. Gerstl, Geocenter Variations Derived From SLR Data to LAGEOS 1 and 2,In: Adam, J. Schwarz, K.-P., Vistas for Geodesy in the New Millennium , IAG Symposia (125), Springer, in print, 2002.

Kaniuth, K., H. M ller, W. Seem ller , Displacement of the space geodetic observatory Arequipa due to recent Earthquakes, Zeitschrift f r Vermessungswesen, Germany, accepted, 2002.

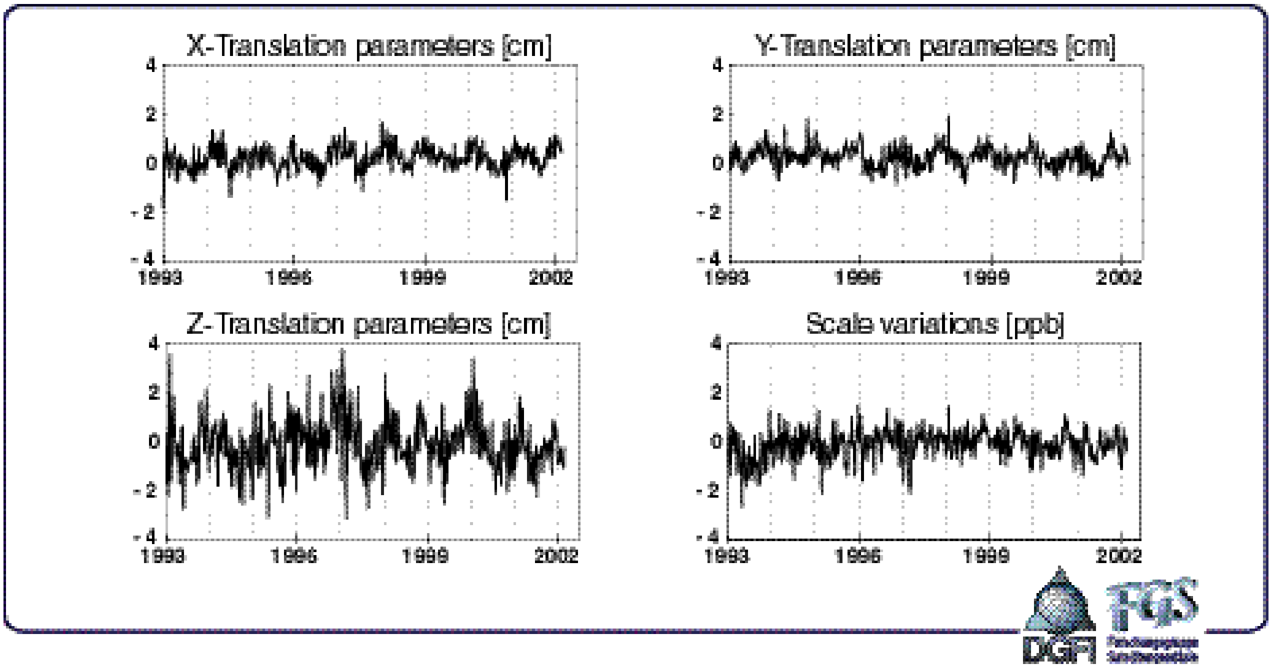


Figure 7.1.2.7-1. Transformation parameters between weekly LAGEOS-1 and -2 combined coordinate solutions and ITRF2000

KEY POINTS OF CONTACT

Horst M ller,
Deutsches Geod tisches Forschungsinstitut
Marstallplatz 8
D-80539 M nchen, Germany
Phone: +49-089-23031217
Fax: +49-089-23031240
E-mail: horst.mueller@dgfi.badw.de

Detlef Angermann
Deutsches Geod tisches Forschungsinst itut
Marstallplatz 8
D-80539 M nchen, Germany
Phone: +49-089-23031217
Fax: +49-089-23031240
E-mail: angerman@dgfi.badw.de

7.1.2.8 EUROPEAN SPACE OPERATIONS CENTER (ESOC)

John Dow and Ren Zandbergen, *ESOC*

INTRODUCTION

One of the tasks of the Navigation Support Office of the European Space Operation Centre (ESOC) is to provide high-precision restituted orbit data for ESA s Earth observation missions, e.g. ERS-1 before its demise, ERS-2 and the future ENVISAT mission (launched March 1, 2002). To achieve this high precision, processing and application of SLR data is one of the requirements. The restituted orbits are based on automatically retrieved quick look laser ranging data, reprocessed fast-delivery altimeter height measurements, and for ENVISAT also DORIS measurements. This task not only supports the provision of the routinely determined and predicted orbits for operational purposes and use in fast-delivery products of the scientific instruments on these missions, but also the computation of monthly sea level anomaly solutions from altimeter data. To accomplish this task, a batch least squares orbit determination sequence including the retrieval and pre-processing of tracking data, and the generation of residual and orbit comparison plots, is run automatically. Five day arc orbit solutions are generated every three days, with a delay of typically one week to allow collection of most of the laser tracking. After each solution, updated reports are made available on the Navigation Support Office s web site (http://nng.esoc.esa.de), and the solution is used as a reference against which the accuracy of the routinely determined orbit is checked.

FACILITIES/SYSTEMS

This activity is carried out using the precise orbit determination (POD) system of ESOC that has evolved out of the routine orbit determination software. While the routine system was frozen at the start of the ERS-2 mission (1995), the POD system has been constantly improved. This system is also being used initially for ENVISAT, but will be replaced by the newly-developed Navigation Package for Earth Observation Satellites (Napeos), after its POD capabilities have been validated.

The computation facilities are mainly SunBlade 1000 workstations that operate under Solaris 8.0.

CURRENT ACTIVITIES

The operational activities for the ERS-2 satellite are on-going as the satellite is still in good shape, although being operated (successfully) in a gyro-less AOCS mode. Therefore, SLR tracking data are still required for the precise orbit determination of ERS-2.

The new generation of orbit determination, prediction and control software Napeos, developed by the team in preparation of ENVISAT and other future Earth Observation missions, will support both the routine operational and high-precision orbit determination of ENVISAT. Since Napeos is already qualified for operations support, the main development effort is being put in the improvement of the high-precision computations, including support of all observation types currently used for geodetic applications.

KEY POINTS OF CONTACT

John Dow
Head of Navigation Support Office
ESA/ESOC, Robert-Bosch Strasse 5
D-64293 Darmstadt, Germany
Tel: +49 6151 902272
Fax: +49 6151 902271
Email: John.Dow@esa.int

Ren Zandbergen
Navigation Support Office
ESA/ESOC, Robert-Bosch Strasse 5
D-64293 Darmstadt, Germany
Tel: +49 6151 902236
Fax: +49 6151 902271
Email: Rene.Zandbergen@esa.int

FUTURE PLANS

SLR data processing will be performed for all current and future ESA satellites equipped with a LRR array (e.g. CryoSat, GOCE), and in test mode for a number of non-ESA LEO missions, such as Jason. In addition, ESOC is responsible for providing the SLR station predictions for ENVISAT and other future ESA satellites.

7.1.2.9 FORSVARETS FORSKNINGSINSTITUTT (FFI)

Per Helge Andersen, *The Norwegian Defence Research Establishment*

INTRODUCTION

FFI has during the last 19 years developed a software package called GEOSAT (Andersen, 1995) for the combined analysis of VLBI, GPS, SLR and other types of satellite tracking data (DORIS, PRARE and altimetry). The observations are combined at the observation level with a consistent model and consistent analysis strategies. The data processing is automated except for some manual editing of the SLR observations.

In the combined analysis of VLBI, GPS, and SLR observations the data are processed in arcs of 24 hours defined by the duration of the VLBI session. The result of each analyzed arc is a state vector of estimated parameter corrections and a Square Root Information Array (SRIF) containing parameter variances and correlations. The individual arc results are combined into a multi-year global solution using a Combined Square Root Information Filter and Smoother program called CSRIFS. With the CSRIFS program any parameter can either be treated as a constant or stochastic parameter between the arcs. The estimation of multi-day stochastic parameters is possible and extensively used in the analyses.

ANALYSIS STRATEGY

Presently, the most important stochastic parameters of the global level state vector are the following: radio source coordinates (1d resolution) of sources with structure index 3 or 4, geocenter coordinates (three day resolution), Earth orientation parameters (one day), the C21 and S21 gravity coefficients (six day), satellite independent SLR ranging biases (15 day), solar radiation pressure scaling and an empirical drag of the LAGEOS satellites (three day), and GPS receiver antenna eccentricity vectors (station dependent time resolution to account for instrumental changes). The reason for including the two gravity coefficients is to account for the fact that errors in the gravity field will map into the estimates of polar motion derived from satellite tracking data. In order to be consistent with VLBI, which is almost independent of gravity, these parameters must be estimated. The arc length of the GPS and LAGEOS satellites is one day.

The main constant parameters of the global state vector are monument coordinates and velocities, GPS and/or SLR eccentricity vectors relative to the station monument if it ia a collocated station, radio source coordinates, relative zenith delay between VLBI and GPS at collocated stations (to account for differences in antenna heights), VLBI antenna axis offsets, and GPS satellite transmitter phase center Z-coordinate offset and nadir-dependent variation (relative to the satellite body-fixed reference frame). The commonly adopted Z-coordinates for the effective phase center of the GPS transmitter antennas are probably have a 1-2 meter error. Results show that the Z-coordinate, as a function of the nadir angle, can be determined to a formal precision of some centimeters (1 sigma). Using the IGS z-coordinate values will result in a scale inconsistent with SLR and VLBI by several ppb. This means that most, but not all, of the error in the GPS phase center offset is absorbed by the estimated clock and ambiguity parameters. However, the phase center variation as a function of the nadir angle is not absorbed by the estimates of any of the parameters. The phase center variation is within approximately 20 mm. One value is estimated for each of the Block II/IIA and Block IIR satellite types. Individual estimates for the different satellites of a specific type show remarkable similarities regarding the nadir dependency.

The status of the analyses is that approximately 3214 daily SLR arcs (with LAGEOS I & II data from 1 Jan 1993 to 31 Dec 2001) have been processed where approximately 744 arcs are combinations with VLBI and approximately 200 arcs are combinations with VLBI, GPS and SLR. Typically, 60 GPS stations are included in each arc. These 3214 arcs have been combined into a global solution using the CSRIFS program. A program called CSRIFS-IERS reads the output of CSRIFS and estimates a time dependent transformation from the internal terrestrial and celestial reference frames to an ITRF reference frame (presently ITRF-2000) and an IERS Celestial reference frame (presently ICRF-95.ext). Since the estimated Earth orientation parameters in principle are 100 % consistent with the internal reference frames the time dependent transformation parameters can be applied to transform the EOP estimates to IERS for comparison with the IERS EOP products. A possible inconsistency between the IERS reference frames and the IERS EOP estimates should in principle be detectable. The CSRIFS-IERS automatically generates SINEX files for the terrestrial and celestial reference frames and the EOP s. These files can be directly submitted to the IERS Product Centers.

During the last year the following improvements have taken place in the GEOSAT software:

- the DE405 planetary ephemerides have been implemented.
- perturbations from the planets Mercury, Mars, Uranus, Neptune and Pluto have been included.
- the IERS-2000 VLBI observation model has been implemented.
- the Mendes *et al*. SLR refraction model has been implemented.
- the following GPS satellites have been down-weighted: PRN 2, 15, 17, 21, and 23.
- a constant GPS satellite phase center offset (Z-coordinate) for each of the Block II/IIA and Block IIR satellite types has been estimated.
- nadir-dependent GPS satellite phase center variations for each of the satellite types have been estimated.

All improvements listed above have been applied in the analysis of the 3214 arcs.

REFERENCES

Andersen, P. H. High-precision station positioning and satellite orbit determination. Ph.D. Thesis, NDRE/publication-95/01094. FFI/E, Box 25, N-2007, Kjeller, Norway.

7.1.2.10 GEOFORSCHUNGSZENTRUM (GFZ) POTSDAM

Franz-Heinrich Massmann, *GeoForschungsZentrum*

DATA PRODUCTS PROVIDED

In 2001, the GeoForschungsZentrum (GFZ) Potsdam continued its ILRS activities of the previous years. The main focus was again on the routine provision of high quality predictions for the ERS-2 and CHAMP satellites. While for the ERS satellite a prediction interval of about two weeks was used with daily updates with time bias functions, for the LEO satellite CHAMP, a prediction generation up to three times per day was established to optimally support the community. The following table summarizes the delivered products.

The orbit prediction products enabled ILRS stations to track both satellites with excellent results. In total 37 stations reported 4196 successfully tracked passes for ERS-2 (111 less than 2000) and 26 stations delivered 1564 passes for the CHAMP satellite.

Table 7.1.2.15-1: ERS-2 and Champ products.

	ERS-2	CHAMP
Orbit Predictions	85	753
Time Bias Functions	276	-
Drag Functions	276	-
Two-Line Elements	85	753
SAO Elements	75	753
Total	797	2259

FURTHER ACTIVITIES

In addition to the operational products mentioned above, the systematic generation of the ERS-2 preliminary and precise orbits based on SLR and PRARE data under ESA contract was continued.

The CHAMP SLR data allowed excellent quality control within the precision orbit determination (POD) process, when computing the orbits based on GPS-SST data from CHAMP. Modeling improvements were easlily seen, especially after introduction of a new global Earth gravity model EIGEN-1, which was determined from GRIM5 normal equations plus several months of CHAMP GPS-SST data. The routine provision of radio occultation data from the GPS receiver onboard of CHAMP resulted in a more rapid generation of Rapid Science Orbits (goal: every three hours).

In view of the upcoming GRACE satellite mission the prediction system was reconfigured, because GFZ will provide predictions for these satellites too.

FUTURE PLANS

The launch of the GRACE satellite in 2002 will add two new satellites to the prediction work, and will allow a much more precise determination of the gravity field of the Earth. As for CHAMP, the SLR measurements will continue to be an important quality control component.

7.1.2.11 GEOSCIENCE AUSTRALIA

Ramesh Govind, *National Mapping Division/Geodesy, Geoscience Australia*

BACKGROUND/INTRODUCTION

The Geoscience Australia Associate Analysis Centre has been routinely processing LAGEOS-1 and LAGEOS-2 data for satellite for orbit determination, station coordinates, Earth Orientation Parameters and SLR station performance monitoring. In addition, on an opportunity or project basis, Stella, Starlette and Etalon data is also processed. This work to-date has been reported in the publication list available on:

http://www.auslig.gov.au/geodesy/techrpts/techrpts.htm.

There is an ongoing emphasis on the co-location and combination of SLR with other space geodetic techniques. The annual activities of observations and processing [since 1997], for the Asia — Pacific Regional Geodetic Project (APRGP) of the Permanent Committee for GIS Infrastructure for Asia and the Pacific (PCGIAP) continues. A new combination solution comprising of four annual campaigns of SLR, VLBI and GPS is currently being finalized. An eight year solution of LAGEOS-1 and LAGEOS-2 results were submitted to the IERS as a contribution for the IERS analysis campaign to align EOP to ITRF2000.

FACILITIES/SYSTEMS

The current computation facilities in the Geoscience Australia Space Geodesy Analysis Centre comprises of four HP workstations [C160, C180, C360 and 2XL2000]. The processing system uses the MicroCosm suite of programs for orbit determination and geodetic parameter estimation as the engine. NASA s SOLVE program is used for the combination solutions. A suite of programs has been developed in-house for analysis and re-formatting. Final results are provided in the SINEX format.

CURRENT ACTIVITIES

The current activities are:

- Participating and contributing to the ILRS Analysis Working Group pilot projects (station coordinates and EOPs, Orbit comparison and Benchmarking).
- Continuing monthly solutions for LAGEOS-1 and LAGEOS-2. The results both as a time series and as SINEX files are available from

  http://www.auslig.gov.au/geodesy/sgc/product.htm.
- Continuing 3-day day arc LAGEOS-1 and LAGEOS-2 station time and range bias based on ITRF2000 set of station coordinates are now available from the above web page.
- Developing the processing software to estimate LOD and pole rates, and inclusion of new tropospheric mapping functions.

FUTURE PLANS

- Plans are to continue to provide both the one-month and the three day arc LAGEOS-1 and LAGEOS-2 solutions.
- Provide global solutions as a full analysis centre to the ILRS when the AWG coordination structures are established.
- Extend routine processing and analysis to TOPEX/Poseidon, Jason-1 for altimeter calibration / validation experiments.
- Compare the SLR solutions for LEOs with the GPS and DORIS determined solutions.
- Continue to provide a station monitoring service using the 3-day arc solutions described above.
- Compare and combine individual SLR solutions submitted by the various analysis centres.
- Contribute by submitting solutions to the IERS SINEX combination campaign.

RELATED PUBLICATIONS

The key publications appear on AUSLIG s Space Geodesy Analysis Centre Web page at:

http://www.auslig.gov.au/geodesy/techrpts/

KEY POINT OF CONTACT

Dr. Ramesh Govind
National Mapping Division/Geodesy
Geoscience Australia
PO Box 2, Belconnen, ACT 2616,
Australia.
Phone: 61 2 62014 371
Fax: 61 2 62014 366
Email: rameshgovind@auslig.gov.au

7.1.2.12 INSTITUTE OF APPLIED ASTRONOMY (IAA)

George Krasinsky, Zinovy Malkin, Nadia Shuygina, Ekaterina Aleshkina, Tamara Ivanova, *Institute of Applied Astronomy*

In 2002, two research groups were involved in independent analysis of satellite and laser ranging data applying two different software packages (ERA and GROSS).

Studies with the ERA package (Krasinsky G.A., Shuigina N.V., Aleshkina E. Yu., Ivanova T.V. referred as IAAK group).

- SLR observations of LAGEOS-1, LAGEOS-2, Etalon-1, Etalon-2 have been processed in the frame of AWG Pilot Project positioning + Earth orientation and submitted to AWG. The approach proposed by AWG was expanded by experiments with combine processing of the SLR observations with VLBI observations of NEOS-A program for the same time interval. In this way the contribution of SLR data not only to determination of the pole coordinates and LOD but also to evaluation of time variations of Celestial Pole could be provided. Kalman filtering was used for modeling of fast changing parameters of VLBI techniques so for modeling the time variations of the all five Earth s orientation parameters. It appeared that in this way some fine effects in the variations of EOPs might be studied. As an example in Fig 1 the obtained time behavior of UT on 28-day interval is presented. The separated points correspond to the least squares solution method obtained in accordance with the recommendations of AWG.
- Database of all SLR observations of Etalon-1, Etalon-2 has been constructed (about 100000 entries) for the planning study of time variations of lower harmonics of geopotential. A preliminary analysis of the dataset by confronting with ephemeredes is carried out.
- LLR observations 1970-2001 have been processed in the two modes: making use of the ephemeredes DE405 and ephemerides obtained by numerical integration in the frame of the ERA package with a new model taking into account an impact of a number of seleno-dynamical parameters. Estimated parameters include lunar Love numbers h_2, l_2, k_2, the tidal lag δ for which statistically significant estimates have been obtained: h_2=0.0861±0.0035, l_2=0.0426±0.0027, k_2=0.0285±0.0008, δ = 2.0559±0.008°. Analysis of the residuals has revealed a sharp change of their time behavior after March 1998 that could not be modeled in other way but including corrections to the coordinates of the lunar reflectors after this date as independent solve-for parameters. As the corrections to coordinates of the reflectors appear to be rather close it is conjectured that near this date a jump of a few centimeters on the position of lunar barycenter with respect to the lunar crust had occurred at this date. For more details see the paper (Krasinsky G.A., 2002).
- Following the global fitting of the whole set of LLR observations 1970-2000, the post-fit residuals for 1995-2000 were analyzed to determine corrections to UT0 and verify whether LLR is a viable component of EOP monitoring.

Computation of EOP with GROSS package (Z.Malkin).

- The group of Lab of Space Geodesy and Earth Rotation continued everyday operative processing of LAGEOS-1 and LAGEOS-2 observations with the GROSS package with delay about two days. A new version of our software implements most of the recommendations of the IERS Conventions (2000) and some other improvements. In result, accuracy of EOP solutions became about 20% better.
- Two final SLR EOP series were computed and submitted to the IERS 2001 Annual Report: EOP(IAA)02L01 computed using LAGEOS-1 observations only (from January 1983), and the series EOP(IAA)02L02 is computed using LAGEOS-1 and LAGEOS-2 observations (from October 1992).

REFERENCES

G.A. Krasinsky, Selenodynamical parameters from analysis of LLR observations of 1970-2001, Communications of IAA RAS, 148, 2002, accessible also via anonymous FTP quasar.ipa.nw.ru/incoming/era as the file LLR.ps.

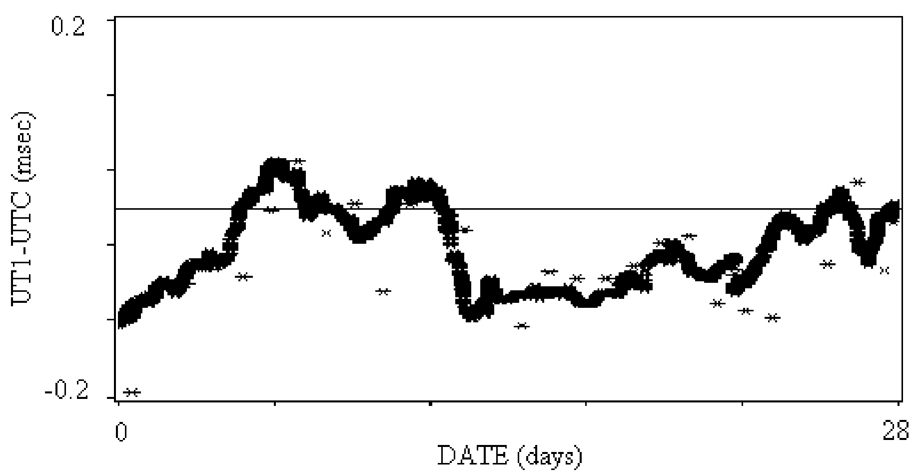


Figure 7.1.2.12-1. UT1-UTC obtained from combining processing of SLR and VLBI data with ERA package.

7.1.2.13 JOINT CENTER FOR EARTH SYSTEMS TECHNOLOGY/GSFC (JCET/GSFC)

Erricos Pavlis, *Joint Center for Earth Systems Technology, University of Maryland*

INTRODUCTION

The AAC at JCET/GSFC continued to support the activities of ILRS and several of its Working Groups during the year 2001. We continued to participate in the IERS/ITRF Pilot Project for TRF definition and the ILRS Pilot Project for the standardization of the SLR data analysis and its products for site and EOP in the form of SINEX file submissions. This past year we submitted to IERS a complete nine year solution based on LAGEOS-1 and LAGEOS-2 data. In addition to these solutions, we have generated solutions that include data from the Etalon-1 and -2 satellites during the period April 1-December 31, 2001 as part of a new Pilot Project of the ILRS AWG.

BACKGROUND

The activities of the AAC are primarily focused on the analysis of SLR data from LAGEOS-1 and LAGEOS-2, with analyses for SLR data obtained on additional satellite targets during specific campaigns of interest (e.g. GPS, GLONASS, Etalon-1 and -2, CHAMP, etc.). The main products are the updated station positions and velocities and the Earth Orientation Parameters, x_p, y_p, and *LODR,* as well as their rates x_p-*dot* and y_p-dot*,* at daily intervals.

In support of the ITRF Pilot Project we also form weekly solutions which are transformed into SINEX format for general distribution. The weekly sets of normal equations are also used to derive a weekly resolution series of *geocenter* offsets from the adopted origin of the reference frame. These series were examined in terms of their spectral content by estimating periodic signals at long and intermediate periods. Comparing them to those obtained from primarily geophysical model predictions, we conclude that they are primarily due to the seasonal redistribution of geophysical fluids in the Earth system.

FACILITIES/SYSTEMS

These are the same as for last year.

CURRENT ACTIVITIES

We continue the generation of our weekly solutions as a contribution to the IERS/ITRF Pilot Project and our own activity of monitoring the episodic and seasonal variations in the definition of the geocenter with respect to the origin of the conventional reference frame. We are also continuing our support for the ILRS Pilot Project, by including EOP rate estimation, utilization of the new mapping function for atmospheric delay, and the analysis of tracking data from Etalon 1 and 2, and the orbit and s/w benchmarking projects. We have also completed a re-analysis of the 9-year series using the new mapping function to identify its impact on the deliverable products. This constitutes our contribution to the IERS for the year 2001 report.

KEY POINT OF CONTACT

Dr. Erricos C. Pavlis (same information as last year)

FUTURE PLANS

ILRS-related activities continue, with emphasis on the near-real-time generation of weekly products and their dissemination via the web. We will also expand our activities to include the data of the new geodetic and oceanographic missions launched during 2001-2002, (e.g. CHAMP, Jason, ENVISAT and GRACE A & B). With regards to the second one and our European Union project GAVDOS to establish an absolute altimeter calibration site at Gavdos/Crete, Greece, we will participate with the SLR, GPS and DORIS data analysis for the CAL-VAL activities during a six month on-site campaign.

REFERENCES, PUBLICATIONS, PRESENTATIONS (2001)

Altamimi Z., D. Angermann, D. Argus, G. Blewitt, C. Boucher, B. Chao, H. Drewes, R. Eanes, M. Feissel, R. Ferland, T. Herring, B. Holt, J. Johannson, K. Larson, C. Ma, J. Manning, C. Meertens, A. Nothnagel, E. C. Pavlis, G. Petit, J. Ray, J. Ries, H.-G. Scherneck, P. Sillard, and M. Watkins, The International Terrestrial Reference Frame and the Dynamic Earth , *Eos Trans. AGU, 82(25)*, pp. 273,278-279, June 19, 2001.

Ciufolini, I. and E. C. Pavlis, The Gravitomagnetic Field and its Measurement with the LAGEOS Satellites , (invited), to appear in *Proceedings of the 3rd William Fairbank Memorial Conference on Gravitational Relativistic Experiments in Space*, Rome, 1998, R. Ruffini (ed.), World Scientific, Singapore , 2001.

Iorio, L. and E. C. Pavlis, Tidal satellite perturbations and the Lense-Thirring effect , *Journal of the Geodetic Society of Japan*, Vol. 47, 1, 2001.

Mendes, V. B., G. Prates, E. C. Pavlis, D. E. Pavlis, and R. B. Langley "Improved Mapping Functions for Atmospheric Refraction Correction in SLR" *GRL,* 29 (10), 2002.

Pavlis, E. C. Dynamical Determination of Origin and Scale in the Earth System from Satellite Laser Ranging, in Proceedings of the *2001 IAG Scientific Assembly: Vistas for Geodesy in the New Millennium*, the *International Association of Geodesy*, Budapest, Hungary, September 2-7, 2001, electronic publication (CD), 2002.

Pavlis, E. C., Geodetic Contributions to Gravitational Experiments in Space , Book chapter, to appear in *Recent Developments in General Relativity, Genoa 2000*, R. Cianci, R. Collina, M. Francaviglia, P. Fr (eds), Springer-Verlag, Milan, (to be published Jan. 2002).

Pavlis, E. C. New Satellite Laser Ranging TRF and EOP Series for Mass Transport Studies in the Earth System, , *Eos Trans. AGU, 82(47)*, Fall Meet. Suppl., Abstract G51C-0254, F293, 2001.

Pavlis, E. C. Earth Orientation Variations from Satellite Laser Ranging (SLR): Quality, Content and Resolution, presented at the *2001 IAG Scientific Assembly: Vistas of Geodesy*, of the *International Association of Geodesy*, Budapest, Hungary, September 2-7, 2001.

Pavlis, E. C. Satellite Laser Ranging constraints on global mass transport in the Earth system, presented at the *European Geophysical Society (EGS) General Assembly*, Nice, France, March, 2001.

Pavlis, E. C. Combination and evaluation of satellite laser ranging contributions towards a single ILRS product, presented at the *European Geophysical Society (EGS) General Assembly*, Nice, France, March, 2001.

Pavlis, E. C. Earth orientation from satellite laser ranging (SLR): quality, content and resolution, presented at the *European Geophysical Society (EGS) General Assembly*, Nice, France, March, 2001.

Pavlis, E. C. and V. B. Mendes Validation of improved mapping functions for atmospheric corrections in laser ranging, presented at the *European Geophysical Society (EGS) General Assembly*, Nice, France, March 2001.

Pavlis, E. C. and L. Iorio, The impact of tidal errors on the determination of the Lense-Thirring effect from satellite laser ranging , *International Journal of Modern Physics D* , 11, 4, pp. 599-618, 2001.

7.1.2.14 NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN: (NASDA)

Takashi Uchimura, *Flight Dynamics Group, NASDA*

INTRODUCTION

The NASDA Associate Analysis Center has been routinely processing Ajisai, LAGEOS-1, LAGEOS-2 and LRE data for precise orbit determination, station coordinates, Earth orientation parameters and SLR station performance monitoring since 23rd August. In addition, on an experiment basis, GPS satellite data is also processed using SLR data and RINEX data. On the other hands, we compared our orbit determination results and prediction results with NERC and HTSI s one as an evaluation of processing accuracy in NASDA. In addition, we prepared for the launch of ADEOS-II satellite. A Major event in 2001 was the launch of LRE (Laser Ranging Equipment) payload by H-IIA launch vehicle No.1 from Tanegashima Space Center. The LRE mission is to help evaluate the H-IIA rocket trajectory, calibration of SLR station from a target which spans a large range of satellite altitude (LRE eccentricity is 0.73), and satellite spin evolution vs. BK7 degradation. We have continued to determine the LRE orbit and have provided IRVs to ILRS station as often as possible.

In the ADEOS-II mission, it became clear that there were visibility problems for ADEOS-II SLR tracking. A detailed analysis of the ADEOS-II satellite, showed that there were some obscured view angles caused by GLI (Global Imager: Optical sensor) for which no SLR returns are possible. We analyzed the following items for ADEOS-II and reported these results at ILRS General Assembly in Nice, France on April 25, 2001.

- SLR restriction area analysis
- Station visibility analysis
- Orbit determination analysis
- Study of SLR operation method

FACILITIES/SYSTEMS

The precise orbit determination system, GUTS , develop ed by NASDA will be improved in two steps. The first step has been completed and is in operation as an experimental OD system for ADEOS-II. The second step for ALOS is now being developed in addition four GPS stations and one SLR station. This system will be performed automatic operation from obtain observation data, orbit determination of several satellites and to deliver orbital information to user. This system is to be main system for precise orbit determination in NASDA and will improved until the 1st quarter of 2003.

CURRENT ACTIVITIES

- Processed Ajisai, LAGEOS-1 and LAGEOS-2 data for orbit determination and generate IRVs on an routine basis. We evaluated orbit determination results and prediction results with NERC and HTSI s one.
- Processed GPS satellite data (QLNP and RINEX) for precise orbit determination and the evaluation of GUTS own system.

- Estimated individual station coordinates, Earth orientation parameters and SLR station performance monitoring when we determined orbit of operation satellites. The results of SLR station performance monitoring is available from http://god.tksc.nasda.go.jp/slreport/
- Comparison of Earth gravity model (JGM-3 vs EGM96) for precise orbit determination using Ajisai and LAGEOS.
- Orbit analysis for LRE which includes station visibility, link budget, orbit determination accuracy and orbit prediction accuracy.
- LRE launch operation. The comparison result (Position difference) between Two Line Elements (TLE) and orbit determination result using SLR is shown in figure 7.1.2.1-14.

FUTURE PLANS

- Establish operation procedure of ADEOS-II in routine operation and preparation for ADEOS-II launch operation.
- Continue to provide IRVs of Ajisai, LAGEOS-1 and LAGEOS-2.
- Continue to process Ajisai, LAGEOS-1, LAGEOS-2 and GPS data for the following estimation; Station coordinates, Earth orientation parameters and SLR station performance monitoring, Solid Earth tide, Coefficient of Earth Gravity Model.

RELATED PUBLICATIONS

The key publications appear on NASDA associate analysis center Web page at:

http://god.tksc.nasda.go.jp/aac/top.html

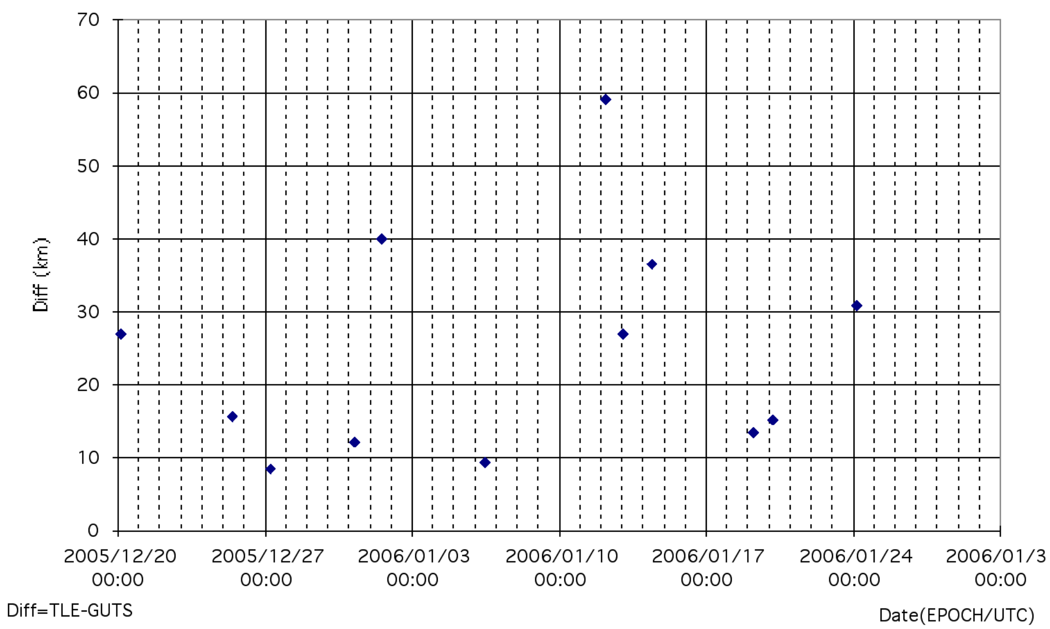


Figure 7.1.2.14-1: LRE Orbit comparison result between TLE and SLR POD (3D position)

KEY POINT OF CONTACT

Takashi Uchimura
Flight Dynamics Group,
Satellite Mission Operations Department,
Office of Satellite Technology,
Research and Applications,
National Space Development Agency of JAPAN

Tel +81 298 68 2624
Fax +81 298 68 2990
e-mail: uchimura@eoc.nasda.go.jp

7.1.2.15 NATURAL ENVIRONMENT RESEARCH COUNCIL (NERC), SPACE GEODESY FACILITY, UK

Graham Appleby, Philip Gibbs and Roger Wood, *NERC*

DAILY QUALITY MONITOR

Our automatic service was considerably upgraded during the year, to include more satellites and short-arc analyses for the whole Network. Long-arc (six-day) results are computed for each ILRS station and shown as residuals from fitted orbits for both LAGEOS and both Etalon satellites on a single plot. Post-fit residual mean and sigma values give an indication of the relative station bias and precision of the data for each satellite during the period, as well as showing current network productivity. For most satellites, short-arc solutions are carried out for all arcs that are tracked pseudo-simultaneously by at least two ILRS stations. The best stations are used to determine small corrections to global long-arc orbit determinations and then residuals are computed for all stations. The results can reveal subtle system changes that occasionally occur during a pass, such as variation of measured range with return signal strength, as well as small errors in the (ITRF2000) values of the station coordinates. All these results are presented daily at:

http://nercslr.nmt.ac.uk/

GLONASS/GPS ORBITAL DETERMINATION

We have continued our study to use SLR observations of the ILRS-campaign GLONASS and GPS satellites to check the quality of the available microwave-based orbital solutions. The SLR observations are used both to generate independent orbits for comparison with the microwave orbits, and in a direct comparison to the positions of the satellites given by the microwave orbits. For the GPS satellites (GPS-35 and -36) the results confirm that on average the satellites are some 40 mm closer to the Earth than is implied by the microwave-based orbits, given of course the accuracy of available data for the location of the on-board retro-reflector arrays. For the GLONASS satellites, after taking into account ranging-system dependent effects due to the large reflector arrays, we find that radial errors are on average close to zero, but that large systematic, possibly seasonal, errors of magnitude up to 30 cm can occur. Unfortunately this work does not impact on the question of the location of the phase centres of the satellites microwave transmitters since the microwave-based orbits are very insensitive to this parameter. The work does, however, suggest that an improvement in the quality of the precise orbits of the GLONASS satellites in particular could be achieved by incorporating SLR data into their derivation.

ILRS ANALYSIS WORKING GROUP PILOT STUDY (POS+EOP)

Effort continues to improve and automate much of the SATAN SLR processing software in order to take part in this pilot project. The analysis was extended during the year to include both LAGEOS and Etalon data and to include solutions for rates of change of Earth rotation parameters, as agreed by the AWG. Monthly LAGEOS solutions for 1999 and LAGEOS+Etalon solutions for 2001 were submitted for subsequent comparison and combination.

SATELLITE PREDICTIONS

Daily and medium-term IRVs along with hourly time bias functions are automatically generated for most of the laser-tracked satellites using up-to-date SLR data. For the designated GLONASS satellites we compute daily IRVS in collaboration with the CODE, Berne, group. All the predictions are available through EDC and on our own anonymous ftp site (mtuftp.nmt.ac.uk; directory nercslr/current), acting as a backup for the official HTSI IRVs.

PHOTOMETRIC OBSERVATIONS OF LAGEOS

In a continuing collaboration with Toshi Otsubo of the Communications Research Laboratory in Japan, we routinely collect 'flash' photometric data during all nighttime ranging sessions to LAGEOS-1 and -2. The data are processed on-site to determine spin rates for both satellites and precise spin axis orientation results for LAGEOS-2.

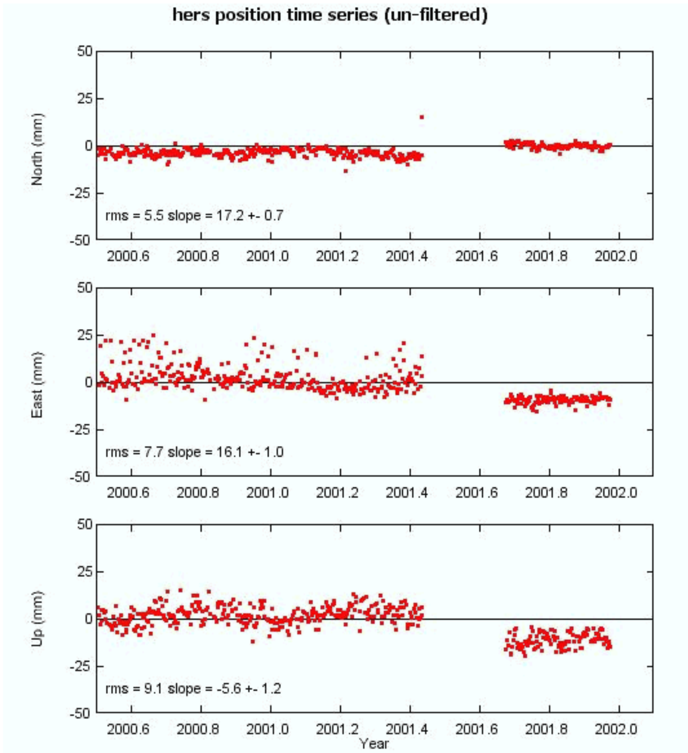


Figure 7.1.2.15-1. Position of Hersmonceux GPS Receiver from SOPAC.

GPS ANSLYSIS

From June 2001 the Ashtech Z18 dual GPS/GLONASS receiver has been contributing regular 30 second sampled data daily to IGLOS. In addition a local archive of one second sampled data is being maintained.

Following the reinstallation of the repaired Ashtech antenna in 2001 August, HERS Z12 data have shown a marked improvement in quality, as shown in the daily coordinates time-series plots below (from Scripps Orbit and Permanent Array Center, San Diego). Data are again being submitted hourly and daily to IGS in the normal way. Daily quality checking software has been developed on site, which will aid in detecting such hardware failures in the future.

RELATED PUBLICATIONS

T. Otsubo, G.M. Appleby and P. Gibbs, 2001. GLONASS Laser Ranging Accuracy with Satellite Signature Effects, *Surveys in Geophysics*, 22, 509-516, published in 2001 in *Proceedings of the 12th International Workshop on Laser Ranging, Matera, Italy:*

Comparisons of SLR Observations and Orbits with GLONASS and GPS microwave Orbits;G.M.Appleby & T.Otsubo.

An overview of Quality Control for the Herstmonceux SLR Station; P.Gibbs, D.Benham, R.Sherwood, P.Standen, D.Walters, R.Wood & G.Appleby.

System Performance Assessment from NERC Simultaneous Arc Analysis; V.Husson, P.Stevens & G.Appleby.

Systematic Range Bias Related to GLONASS Reflector Array; T.Otsubo, G.Appleby & P.Gibbs.

Abstract in *Geophysical Research Abstracts, volume 3, 2001*. Monitoring GPS and GLONASS microwave orbits using SLR; G.M.Appleby & T.Otsubo.

ACKNOWLEDGEMENTS

The NERC Space Geodesy Facility at Herstmonceux and at Monks Wood, UK, is funded by the UK Natural Environment Research Council in collaboration with the British National Space Centre and the Ministry of Defense.

7.1.2.16 OCA/CERGA ASSOCIATE ANALYSIS CENTER

Pierre Exertier, Jo lle Nicolas, Pascal Bonnefond, David Coulot, *Centre d'Etude et de Recherche en G ody-namique et Astrom trie, GRASSE – FRANCE*

INTRODUCTION

Besides its involvement in the SLR data acquisition through operation of the Grasse stations (SLR, LLR (high altitude satellites and Moon), and FTLRS deployed in the Corsica island since January 2002, the OCA/CERGA is actively contributing to the ILRS as an Associate Analysis Center (AAC).

We have participated (1) in the analysis of SLR data for calibration/validation (CAL/VAL) activities (TOPEX/Poseidon project in view of Jason-1, GPS, CHAMP, etc.), and (2) in the analysis of LAGEOS-1 and -2 SLR data for carefully analyzing site coordinate time series - in addition to instrument stability including uncertainties relative to atmospheric propagation.

FACILITIES/SYSTEMS

The current computation facilities in the OCA/CERGA consist of two Compaq (DEC-Alpha) workstations. The processing system uses the GINS (GRGS/CNES) software for orbit determination and a suite of locally developed programs for space geodesy analysis.

Concerning geodetic techniques, our AAC is supporting several instruments in collaboration with CNES (Toulouse) and IGN (Paris). These instruments are :

- three laser ranging stations: SLR, FTLRS, and LLR, and
- one permanent GPS receiver.

BACKGROUND

The activities of the OCA/CERGA AAC are primarily focused on the analysis of SLR data from altimeter satellites such as TOPEX/Poseidon (T/P). We have developed a short arc orbit technique for orbit validations and positioning-collocation experiments (geometric approach). This method is based on rigorous adjustment criteria, which can be applied to the entire laser network. These developments and capabilities have been put on a dedicated web site in order to permit the quasi-immediate and continuous validation of T/P orbits. This site can be used to evaluate results of the overall mission; local radial, tangential, and normal orbit residuals; and SLR residuals, eventually per station, are also presented.

After the long phase of improvements, the French Transportable Laser Ranging Station (FTLRS) began observations in its new configuration in summer 2001. In order to validate the new performances of the FTLRS, we used the unique opportunity of having three independent laser ranging stations very close one to each other (about 20 m): a classical satellite laser ranging station (SLR), the French Lunar laser ranging station (LLR), and the FTLRS. Therefore, we performed a collocation experiment between these three instruments from September to December 2001.

This collocation experiment is based on common observations between the three stations on LAGEOS—1 and —2 satellites (altitude of about 6000˚km).

Our analysis, based on all the common normal points, gave us a value of the relative range biases between these three instruments for the two LAGEOS satellites.

- The bias between the Grasse SLR fixed station and the FTLRS is of 4.6 mm on LAGEOS—1 and of 5.7 mm on LAGEOS—2.
- The biases between the Lunar Laser Ranging station and the FTLRS are of 18.6 mm and 18.4 mm for LAGEOS—1 and —2 respectively.
- The range measurement differences between the Lunar Laser Ranging station and the fixed Satellite Laser Ranging station are 13.9 and 12.1 mm respectively.

Combining these LAGEOS–1 and –2 solutions (weighted by the number of normal points), we determined the following relative range biases between the stations: 5.4 mm between the SLR station and the FTLRS, 18.5 mm between the LLR and the FTLRS, and of 13.1 mm between the LLR and the SLR stations. There are technological explanations for the 1 cm difference in the range measurements between the two Grasse fixed stations. The explanation is probably linked to a difference in terms of detection level (multi-photon for the SLR and single photo-electron for the LLR) which may introduce a difference in the satellite signature correction, and may be linked to the systematical LLR return detector center-edge effect on LAGEOS satellites (of about 60 ps which corresponds to a range of about 9 mm).

We can so conclude that the improvements of the FTLRS were successful and that the FTLRS seems to be better than the Grasse SLR fixed station. We will have confirmation of this with the analysis of the data of the 2002-campaign performed in Corsica for the Jason-1 CAL/VAL experiment.

CURRENT ACTIVITIES

- Combination of SLR, GPS and gravimetry time series. Analysis of possible regional sources of seasonal variations of g and of the positioning vertical component,
- CAL/VAL activities, see on : http://grasse.obs-azur.fr/cerga/gmc/calval/alt/
- Realization of the Jason-1 CAL/VAL campaign which has been carried out in Corsica (the official site of CNES),

FUTURE PLANS

The OCA/CERGA AAC will continue to develop the same kind of laser data analysis. Our activities for 2002-2003 will be centered on:

- Jason-1 CAL/VAL campaign (realization and data processing).
- realization of the EU GAVDOS project in Crete

Figure 7.1.2.16-1. Laser Ranging at the Grasse Site.

RELATED PUBLICATIONS

Exertier Pierre, Pascal Bonnefond, Joëlle Nicolas, and François Barlier, *Contributions of Satellite Laser Ranging to past and future radar altimetry missions*, Surveys in geophysics, vol 22(5-6), 491

KEY POINT OF CONTACT

Dr. Pierre Exertier
OCA/CERGA
Avenue Nicolas Copernic
06130 Grasse
France

Tel: +33-(0)439405386
Fax: +33-(0)493405333
e-mail: Pierre.Exertier@obs-azur.fr

7.2 LUNAR LASER RANGING

7.2.1 INTRODUCTION

Peter Shelus, *University of Texas at Austin*

Lunar laser ranging (LLR) is one of the more modern and exotic forms of astrometry. It measures the round-trip travel time of a laser pulse that is emitted from a station on the Earth and returns, after being reflected off of a retroreflector array on the Moon. The analysis of this constantly changing distance, using several stations on the Earth and several retroreflectors on the Moon, provides a diversity of terrestrial, lunar, solar system, and relativistic results. After almost 35 years of operation, LLR remains a technically challenging task. With several tens of highly efficient artificial satellite ranging stations around the world, only two of them have the capability of routinely ranging to the Moon. One of them is located in the United States, at McDonald Observatory. The other is in the south of France, near Nice, at the Observatoire de la Cote d Azur. A third station, the MLRO, in Matera, Italy is on the verge of becoming operational in LLR. A totally new LLR station is being constructed at the Apache Point Observatory in New Mexico in the USA.

The data that is gathered by the LLR stations form a foundation upon which a large number of astronomical disciplines rely. They provide a valuable multi-disciplinary analytical tool, the benefits of which are registered in such areas as the solid Earth sciences, geodesy and geodynamics, Solar System ephemerides, terrestrial and celestial fundamental reference frames, lunar physics, general relativity and gravitational theory. They contribute to our knowledge of the precession of the Earth s spin axis, the 18.6 year lunar induced nutation, polar motion and Earth rotation, the determination of the Earth s obliquity to the ecliptic, the intersection of the celestial equator and the ecliptic (the equinox), lunar and solar solid body tides, lunar tidal deceleration, lunar physical and free librations, as well as energy dissipation in the lunar interior. They determine Earth station and lunar surface retroreflector location and motion, the Earth-Moon mass ratio, lunar and terrestrial gravity harmonics and Love numbers, relativistic geodesic precession and the strong equivalence principle of general relativity.

7.2.1.1 PARIS OBSERVATORY LUNAR ANALYSIS CENTER (POLAC)

Jean Chapront, M. Chapront-Touz , G rard Francou, *Observatoire de Paris*

INTRODUCTION

The lunar analysis center POLAC is a part of the Department of Fundamental Astronomy at Paris Observatory (DANOF). Beginning in 2002, the work of POLAC will be transferred to the new department SYRTE (SYst me de R f rence Temps-Espace). We work in cooperation with the LLR team of CERGA at Grasse (France). For many years our team has been involved in celestial mechanics studies, especially in the development of analytical solutions for lunar and planetary motions for our publication of solar system bodies ephemerides. Since 1997, we have cooperated with the IERS and our main goals are: to improve the analytical solutions of the orbital and rotational motions of the Moon, to determine the orientation of the dynamical celestial reference frame, and to produce Earth rotation parameters, Universal Time (UT0-UTC) and variation of latitude (VOL) series.

ACTIVITIES

An analysis of Lunar Laser Ranging (LLR) observations from January 1972 to April 2001 was performed, and a new solution for the lunar orbital motion and librations named S2001 was constructed. The solution methodology was modified by incorporating improvements to the statistical treatment of the data, new nutation and libration models, and the addition of the position of the observing stations to the list of the fitted parameters.

The most recent results concern:

- the secular acceleration of the Moon's mean longitude due to the tidal forces, (table 7.2.1.1-1)
- the correction to the IAU76 luni-solar constant of precession (table 7.2.1.1-2).

In addition to the positioning of the dynamical reference system with respect to the ICRS, a fit of the positions and velocities of the LLR stations was done.

The total post-fit residuals fit (root mean square error) is within two to three centimeters in the lunar distance for recent observations provided by the two modern instruments: MLRS2 for McDonald and YAG for the CERGA. The following tables present some of our results.

Table 7.2.1.1-1: Tidal acceleration of the lunar mean longitude (in arcsecond/cy^2) compared with the Jet Propulsion Laboratory values.

Sources	Value	Publication
S2001	-25.858	2001
JPL DE405	-25.826	1998
JPL DE403	-25.580	1995
JPL DE200	-23.895	1982

Table 7.2.1.1-2: Correction to the IAU 1976 precession constant Δp in (in arcsecond/cy) and offsets of Celestial Ephemeris Pole at J2000.0 -ψ sinε and $\Delta\varepsilon$ (in arcsecond).

Method Source	Δp	ψ sinε	$\Delta\varepsilon$
LLR S2001	0.302±0.003	0.0177±0.0004	0.0054±0.0002
VLBI Fukushima	0.297±0.004	0.0167±0.0005	0.0049±0.0003

The uncertainties are formal errors

Table 7.2.1.1-3. Time distribution of the post-fit residuals (rms)

Observatory and *instrument*	Time Interval	S2001 rms	N
McDonald	1972-1975	43.5	1487
Telescope 2.70 m	1976-1979	27.7	1035
and *MLRS1*	1980-1986	29.1	990
CERGA *Rubis*	1984-1986	18.7	1165
Haleakela	1987-1990	6.3	451
McDonald	1987-1991	5.8	232
MLRS2	1991-1995	4.6	586
	1995-2001	3.3	1669
CERGA	1987-1991	5.3	1574
Yag	1991-1995	3.9	2044
	1995-2001	3.0	3273

N is the number of LLR normal points involved.

REFERENCES

Chapront, J., Chapront-Touz , M., 1997, Celest. Mech. 66, 31.

Chapront, J., Chapront-Touz , M., Francou, G., 1999, Astron. Astrophys. 343, 624.

Chapront, J., Chapront-Touz , M., Francou, G., 2002, Astron. Astrophys. 387, 700.

Fukushima, T., 2000, Report on Astronomical Constants, IAU General Assembly, Manchester.

POINTS OF CONTACT

Authors: Jean Chapront, Michelle Chapront-Touze, Gerard Francou
Address: Observatoire de Paris (SYRTE), 61 avenue de l'Observatoire, 75014 Paris, France
Contact : jean.chapront@obspm.fr

7.2.1.2 FORSCHUNGSEINRICHTUNG SATELLITENGEOD SIE (FESG) / INSTITUT F R ERDMESSUNG (IFE)

J rgen M ller, *FESG/IFE*

STATUS

At the FESG (Research Facility for Space Geodesy), the LLR data have been analyzed in March 2001 to provide a set of station coordinates (SSC) in SINEX format as well as Earth orientation parameters (EOP) for the IERS annual report. The parameter determination was based upon all LLR data available since 1970, about 14,350 normal points.

The investigation of tidal effects has been finished (first results were shown in the ILRS annual report 2000) and the main results have been published; see M ller and Tesmer (2002) and M ller et al. (2002).

We have improved the software for the detection of the real lunar returns in the very noisy, raw observations at Wettzell. To improve the visibility of the LLR measurements in the noise, a semi-pulse pattern was incorporated in the transmitted signal (and thus in the received time series). This specific feature could be used to detect the real lunar returns in the raw observations by applying a correlation procedure. Figure 7.2.1.2-1 shows the improvement in the processed data. On the left hand side, the original observations are indicated in the usual histogram representation, where no lunar returns can be identified at all. On the right hand side, the resulting post-correlation histogram based upon the same observational data as before, is shown. The lunar returns are clearly visible now. For more details see Meyer et al. (2002).

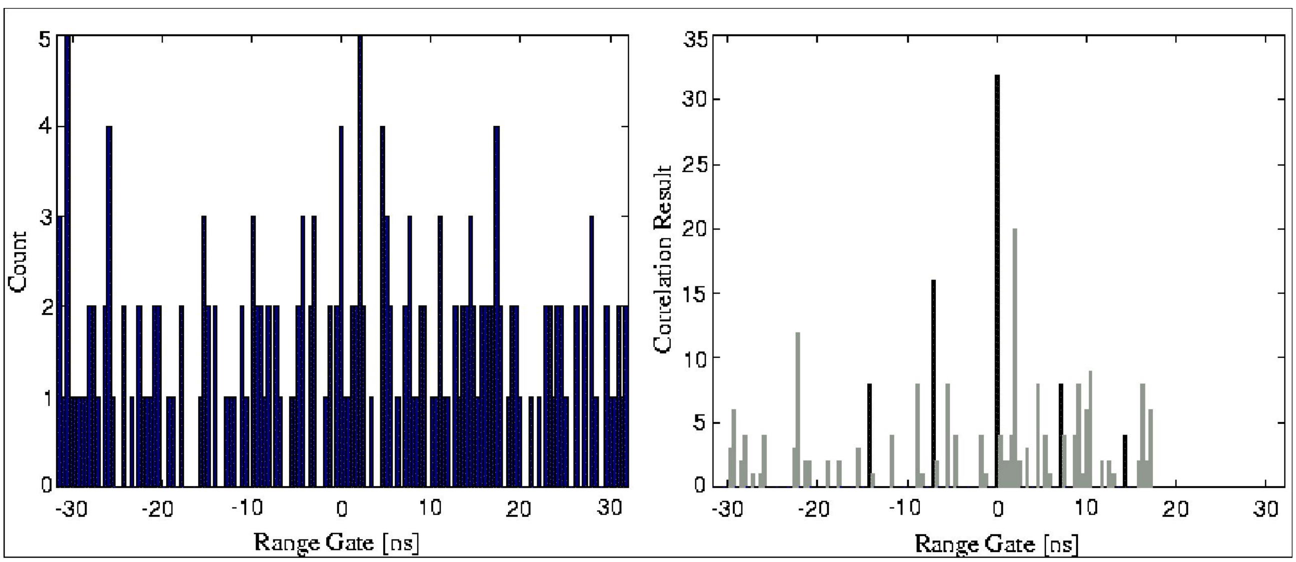


Figure 7.2.1.2-1: Comparison of LLR observations before and after applying the correlation procedure.

CURRENT ACTIVITIES AND FUTURE PLANS

In October 2001, J rgen M ller moved from the Technical University Munich to the Institute of Geodesy (Institut f r Erdmessung) at the University of Hannover, where the LLR activities will be continued in cooperation with the FESG. As a first step, the software has been implemented on a PC. Now the fine-tuning of the software is under progress, to be able to provide the LLR parameters with highest accuracy.

Moreover, we plan to prepare a further version of the LLR software package for implementation at Wettzell, which shall be used for the calculation of the normal points as well as for the computation of the standard LLR products, i.e. EOPs and station coordinates.

REFERENCES

Meyer F., Seitz F., M ller J. (2002), An Algorithm for Reliable Normal Point Calculation of Noisy LLR Measurements in: Laser Radar: Ranging and Atmospheric Lidar Techniques III, SPIE-Proceedings, Vol. 4546, No. 29, Eds. U.Schreiber, C.Werner, G.Kamerman, U.Singh, P. 154-159.

M ller J., Chapront J., Ries J.G. Williams J. (2002), LLR and Tidal Effects , Bulletin D'Informations Marees Terrestres (BIM), Vol. 134, ed. by B.Ducarme, P. 10553-10557.

M ller J., Tesmer V. (2002), Investigation of Tidal Effects in Lunar Laser Ranging , Journal of Geodesy, Vol. 76, P. 232-237.

KEY POINT OF CONTACT

Prof. Dr.-Ing. J rgen M ller
University of Hannover
Institut f r Erdmessung
Schneiderberg 50
30167 Hannover, Germany
e-mail:° mueller@ife.uni-hannover.de
phone: ++49 (0)511-762-3362
fax :°°°° ++49 (0)511-762-4006

7.2.1.3 *JET PROPULSION LABORATORY (JPL)*

J. G. Williams, D. H. Boggs, J. O. Dickey, and J. T. Ratcliff, *Jet Propulsion Laboratory*

STATUS

Analyses of laser ranges to the Moon are used for a variety of investigations: lunar science, gravitational physics, geodesy, geodynamics and astronomy. Lunar Laser Ranging (LLR) analyses provide determinations of the Moon's tidal acceleration, orbit, three-dimensional rotation (physical libration), and tidal deformation, determinations of fundamental constants and the Earth's rotation, orientation, precession, station locations and motions, and tests of gravitational physics. Unique contributions from LLR include: detection of a molten lunar core; measurement of tidal dissipation in the Moon; an accurate test of the principle of equivalence for massive bodies (strong equivalence principle); and detection of lunar free librations.

ACTIVITIES

Lunar laser ranges (LLR) are regularly received from the Observatoire de la Cote d'Azur (Grasse 7845) and McDonald Observatory (7080) sites. Four lunar retroreflector arrays are ranged, but about 80% of the data comes from the largest array at the Apollo 15 site. Global solutions for a number of parameters fit range data from recent years with a weighted rms scatter of 17 mm. The ranges are processed at frequent intervals for Earth rotation information and the resulting sequences of UT0 and variation of latitude values for the two stations are input to the JPL Earth rotation filter. Tables of Earth rotation derived from a combination of techniques are available at the ftp site:

ftp://euler.jpl.nasa.gov/keof/combinations

Files and documentation for lunar and planetary ephemerides and lunar physical libration are available to the scientific community at the web site http://ssd.jpl.nasa.gov/horizons.html.

The tidal acceleration of the Moon has been computed for several ephemerides based on iterated solutions. The acceleration in mean longitude due to dissipative effects is -25.7 arcs/cent^2, of which -26.0 arcsec/cent^2 is due to tides on Earth and +0.3 arcs/cent^2 is due to tidal and fluid core dissipation in the Moon. The tidal increase in semimajor axis is 38 mm/yr.

Dissipation in the Moon is investigated in (Williams, 2001). The solid-body tidal Q is low and has a weak dependence on tidal period. A fluid core is indicated with a size about 20% of the Moon's dimension. An oblate core-mantle boundary (CMB) can influence the determination of the Love number k_2. Preliminary attempts allowing for CMB oblateness give a lunar Love number k_2=0.0266, with uncertainty 0.0027 (5). A low velocity zone may be present above the core.

Uncertainties continue to tighten for tests of gravitational physics. The Earth and Moon are accelerated alike in the Sun's gravitational field to within 1.5 parts in 10^{13} (Anderson, 2001). This equivalence principle test is sensitive to differences between Earth and Moon due to both composition and gravitational self-energy. Tests of the relativistic geodetic precession and the Parameterized Post Newtonian (PPN) beta and gamma agree with Einstein's General Relativity (Williams, 2002). The equivalence principle test limits the beta uncertainty to 0.0005 (Anderson, 2001). The gravitational constant G has no detectable rate for dG/dt / G within 1.1×10^{-12} /yr (Williams, 2002).

FUTURE PLANS

Data analysis models will be improved and lunar laser ranges will be processed. Earth rotation results will continue to be generated. Investigation of lunar science and gravitational physics will continue along with lunar ephemeris and physical libration development. Ranges from several sites on the Earth to the several retroreflectors on the Moon are valuable. We will process data from sites with existing and future (Murphy, 2001) lunar capability.

RECENT PUBLICATIONS

J. D. Anderson and J. G. Williams, Long-Range Tests of the Equivalence Principle, Classical and Quantum Gravity, 18, 2447-2456, 2001.

J. G. Williams, D. H. Boggs, C. F. Yoder, J. T. Ratcliff, and J. O. Dickey, Lunar Rotational Dissipation in Solid Body and Molten Core, J. Geophys. Res. Planets, 106, 27933-27968, 2001.

T. M. Murphy, Jr., J. D. Strasburg, C. W. Stubbs, E. G. Adelberger, J. Angle, K. Nordtvedt, J. G. Williams, J. O. Dickey, and B. Gillespie, "The Apache Point Observatory Lunar Laser-Ranging Operation (APOLLO)", Proceedings of 12th International Workshop on Laser Ranging, Matera, Italy, November 2000, in press, 2002. A web version is located at the site http://geodaf.mt.asi.it/html/news/iwlr/index.htm

J. G. Williams, D. H. Boggs, and J. O. Dickey, Lunar Laser Tests of Gravitational Physics, Proceedings of Ninth Marcel Grossmann Meeting (World Scientific Publ.), in press, 2002, there is a short print version and a longer electronic version.

ABSTRACT

J. G. Williams, D. H. Boggs, J. T. Ratcliff and J. O. Dickey, Lunar Love Numbers and the Deep Lunar Interior, abstract #2033 of the Lunar and Planetary Science Conference XXXIII, March 11-15, 2002.

KEY POINTS OF CONTACT

Name	e-mail	Telephone No.
James G. Williams	James.G.Williams@jpl.nasa.gov	(818) 354-6466
Dale H. Boggs	Dale.H.Boggs@jpl.nasa.gov	(818) 354-1630
Jean O. Dickey	Jean.O.Dickey@jpl.nasa.gov	(818) 354-3235
J. Todd Ratcliff	James.T.Ratcliff@jpl.nasa.gov	(818) 354-0204

All Key Points of Contact can be reached at:

Jet Propulsion Laboratory
Mail Stop 238-332
4800 Oak Grove Drive
Pasadena, CA 91109-8099
FAX: (818) 393-6890

7.2.1.4 UNIVERSITY OF TEXAS MCDONALD OBSERVATORY LUNAR ANALYSIS CENTER (UTXM)

Judit Ries, *University of Texas at Austin*

STATUS

The University of Texas McDonald Observatory Lunar Analysis Center (UTXM) is operating within the Department of Astronomy of the University of Texas at Austin, in conjunction with the McDonald Laser Ranging Station (MLRS) near Ft. Davis Texas. The Center has been providing monthly Earth Orientation Parameters (EOP) from 1989 through 2000, switching to annual production in 2001, and also supplies predictions for lunar data acquisition and carries out internal quality control.

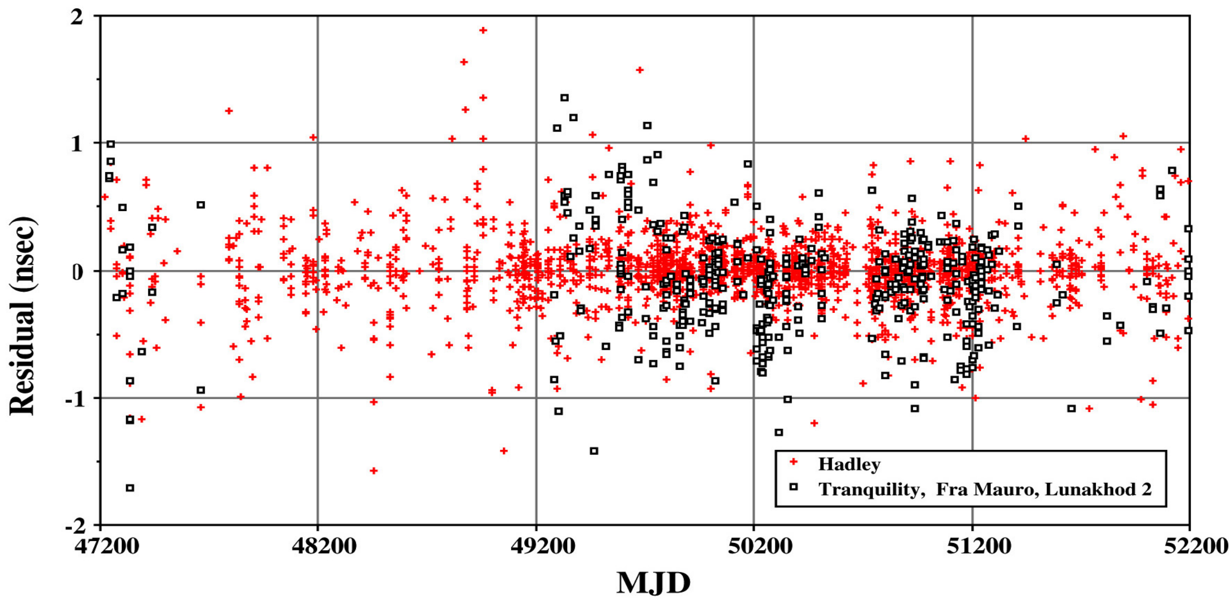


Figure 7.2.1.4- 1. Residuals for 2578 MLRS normal points including all retro-reflectors February 1988 to December 2001

CURRENT ACTIVITIES

- Using all available the LLR data, we adjust a number of global parameters of the Earth Moon system and station and reflector parameters. We assume that the remaining nightly signature is due to UT1R error in the smoothed a priori series we use. For nights with sufficient data we can remove this signal. The residuals show a normal distribution with a mean of 1.15×10^{-2} nsec, and 0.22 nsec weighted RMS. The fit to the data from the Mt. Fowlkes site is shown on Figure 7.2.1.4-1. (The slope of the linear fit to the residuals is practically zero, 1.1 $\times 10^{-5}$ nsec/day).
- We have calculated a total of 34 UT0 - UTC values in 2001, 26 from OCA and 8 from MLRS reflector 3 (Hadley, Apollo 15), data, based on 382 normal point provided by the two active stations. Only nights with at least 3 normal points and at least 1.5 hours span were accepted, and UT0 - UTC and $\Delta\phi$ were calculated using an iterative least square analysis.
- We converted the UT0 and variation of latitude estimates to UT2-TAI using the a priori polar motion values to compare our results with IERS Bulletin A EOP series, as seen on Figure 7.2.1.4-2.

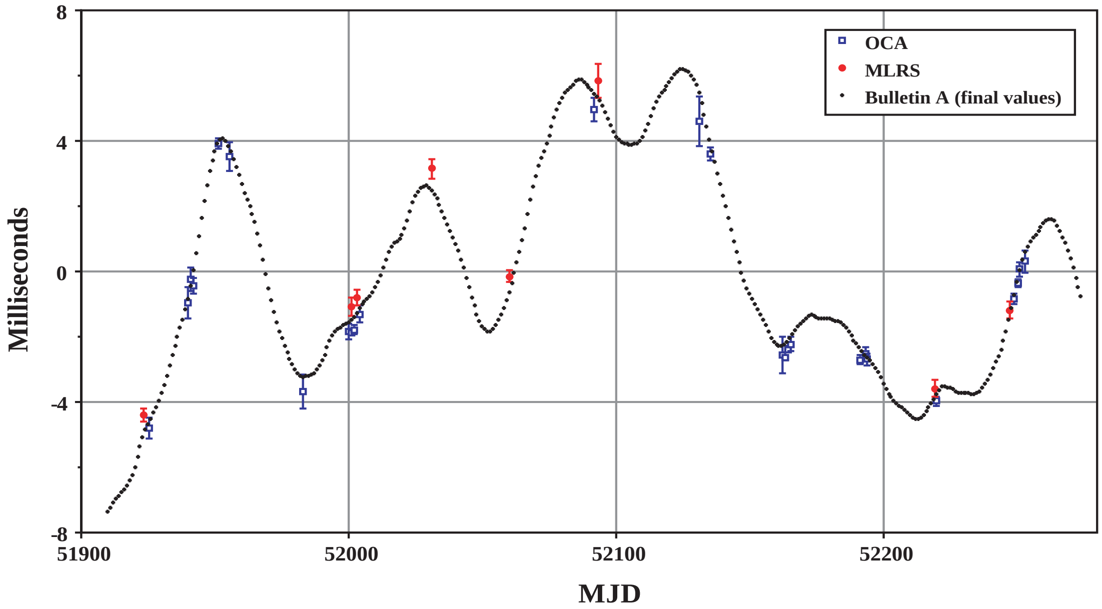


Figure 7.2.2.4-2. UT2-TAI with -0.589 msec/day slope removed (January 1 – December 31, 2001)

FUTURE PLANS

We will continue to provide annual EOP series to the community, while improving the quality and the stability of our solution. We hope to work on the simultaneous processing of LLR data and SLR data as the second step in truly unifying laser data handling.

REFERENCES

Aoki, S., Guinot, G. H., Kaplan, H., Kinoshita, D. D., McCarthy, and P. K. Seidelmann, (1982). "The New Definition of Universal Time", Astron. Astrophys. 105, 359-361.

UT0 and Variation of Latitude Determination from Lunar Laser Ranging Observations for 1969-1998, J. Gy rgyey Ries, R. L. Ricklefs, P. J. Shelus, J. R. Wiant, 1998 IERS Annual Report, Observatoire de Paris, France, 1999.

A Summary of LLR Activity and Science Results, P. J. Shelus, J. G. Ries, J. G. Williams, J. O. Dickey, Proceedings of the 12th International Workshop on Laser Ranging, Matera, Italy, 13-17 November 2000.

KEY POINT OF CONTACT

Author : Judit Gy rgyey Ries
Address : The University of Texas at Austin, Austin, TX 78712, USA
Contact: moon@astro.as.utexas.edu

SECTION 8

ILRS INFORMATION

SECTION 8 - ILRS INFORMATION

8.1 ILRS TERMS OF REFERENCE

1.0 INTRODUCTION

1.1 Charter and Affiliations

The International Laser Ranging Service (ILRS) is an established Service within Section II, Advanced Space Technology, of the International Association of Geodesy (IAG). The primary objective of the ILRS is to provide a service to support, through Satellite and Lunar Laser Ranging data and related products, geodetic and geophysical research activities as well as International Earth Rotation Service (IERS) products important to the maintenance of an accurate International Terrestrial Reference Frame (ITRF). The service also develops the necessary standards/specifications and encourages international adherence to its conventions.

1.2 Services

The ILRS collects, merges, archives and distributes Satellite Laser Ranging (SLR) and Lunar Laser Ranging (LLR) observation datasets of sufficient accuracy to satisfy the objectives of a wide range of scientific, engineering, and operational applications and experimentation. These data sets are used by the ILRS to generate a number of scientific and operational data products including but not limited to:

- 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
- Centimeter accuracy satellite ephemerides
- Fundamental physical constants
- Lunar ephemerides and librations
- Lunar orientation parameters

The accuracy of SLR/LLR data products is sufficient to support a variety of scientific and operational applications including:

- Co-determination, with other space geodetic techniques, of the International Terrestrial Reference Frame (ITRF), especially as it relates to center-of-mass and scale
- Realization of global accessibility to and the improvement of the International Terrestrial Reference Frame (ITRF)
- Monitoring three dimensional deformations of the solid Earth
- Monitoring Earth rotation and polar motion
- Support the monitoring of variations in the topography and volume of the liquid Earth (ocean circulation, mean sea level, ice sheet thickness, wave heights, etc.)
- Tidally generated variations in atmospheric mass distribution
- Calibration of microwave tracking techniques
- Picosecond global time transfer experiments
- Astrometric observations including determination of the dynamic equinox, obliquity of the ecliptic, and the precession constant
- Gravitational and general relativistic studies including Einstein's Equivalence Principle, the Robertson-Walker b parameter, and time rate of change of the gravitational constant, G
- Lunar physics including the dissipation of rotational energy, shape of the core-mantle boundary (Love Number k2), and free librations and stimulating mechanisms
- Solar System ties to the International Celestial Reference Frame (ICRF)

1.3 Amendments to the ILRS Terms of Reference

A proposal to amend the ILRS Terms of Reference can be made in writing to the Chairperson of the Governing Board (see Section 3.0) by any ILRS Associate Member (see Section 4.1). Proposed amendments will be forwarded by email to all ILRS Associate Members of record for comment and amended as necessary by the Chairperson prior to a Governing Board vote. Associate Members will be given two weeks to comment. Final approval of any such amendment requires a 2/3 affirmative vote of the Governing Board. Proposed amendments to the Terms and subsequent Board actions will be summarized and presented to the Associate Members by the Chairperson at the next General Assembly.

2. PERMANENT COMPONENTS OF THE ILRS

The ILRS accomplishes its mission through the following permanent components:

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

The characteristics and responsibilities of these entities is described in the following subsections.

2.1 Tracking Stations and Subnetworks

ILRS Tracking Stations range to a constellation of approved satellites (including the Moon), contained in a list of satellites compiled and approved by the ILRS Governing Board, through the use of state of the art laser tracking equipment and data transmission facilities which allow for a rapid (at least daily) data transmission to one or more Operations and/or Data Centers (see below). The stations must meet data accuracy, quantity, and timeliness requirements which are specified in separate documents. The tracking data produced by the ILRS stations are regularly and continuously analyzed by at least one ILRS Analysis Center or one mission-specific Associate Analysis Center. Tracking Stations may be organized into regional or institutional subnetworks.

2.2 Operations Centers

The Operational Centers are in direct contact with tracking sites organized in a subnetwork. Their tasks typically include the collection and merging of data from the subnetwork, initial data quality checks, data reformatting into a uniform format, compression of data files if requested, maintenance of a local archive of the tracking data, and the electronic transmission of data to a designated ILRS Data Center. Operational Centers may also provide the tracking sites with sustaining engineering, communications links, and other technical support. In addition, Operational Centers can perform limited services for the entire network. Individual tracking stations can also perform part or all of the tasks of an Operational Center themselves.

2.3 Data Centers

2.3.1 Regional Data Centers

The Regional Data Centers reduce traffic on electronic networks. They collect reformatted tracking data from Operational Data Centers and/or individual tracking stations, maintain a local archive of the data received and, in some cases, transmit these data to the Global Data Centers. Regional Data Centers may also meet the requirements for Operational Centers and Global Data Centers (as defined in the previous and following paragraphs) of strictly regional network operations and duplicate activities of Global Data Centers to facilitate easy access to the information and products.

2.3.2 Global Data Centers

The Global Data Centers are the primary interfaces to the Analysis Centers and the outside user community. Their primary tasks include the following:

- Receive/retrieve, archive and provide on-line access to tracking data received from the Operational/Regional Data Centers
- Provide on-line access to ancillary information such as site information, occupation histories, meteorological data, site specific engineering data, etc.
- Receive/retrieve, archive and provide on-line access to ILRS scientific data products received from the Analysis Centers
- Backup and secure ILRS data and products

2.4 Analysis Centers

The analysis centers fall into three categories: Analysis Centers, Lunar Analysis Centers, and Associate Analysis Centers.

2.4.1 Analysis Centers

The Analysis Centers receive and process tracking data from one or more data centers for the purpose of producing ILRS products. The Analysis Centers are committed to produce the products, without interruption, at an interval and with a time lag specified by the Governing Board to meet ILRS requirements. The products are delivered to the Global Data Centers, to the IERS (as per bilateral agreements), and to other bodies, using designated standards. At a minimum, the Analysis Centers must process the global LAGEOS-1 and LAGEOS-2 data sets and are encouraged to include other geodetic satellites in their solutions.

The Analysis Centers provide, as a minimum, Earth orientation parameters on a weekly or sub-weekly basis, as well as other products, such as station coordinates, on a yearly basis or as otherwise required by the IERS. The Analysis Centers also provide a second level of quality assurance on the global data set by monitoring individual station range and time biases via the fitted orbits (primarily the LAGEOS 1 and 2 satellites) used in generating the quick-look science results.

2.4.2 Associate Analysis Centers

Associate Analysis Centers are organizations that produce special products, such as satellite predictions, time bias information, precise orbits for special-purpose satellites, station coordinates and velocities within a certain geographic region, or scientific data products of a mission-specific nature. Associate Analysis Centers are encouraged to perform additional quality control functions through the direct comparison of individual Analysis Center products and/or the creation of "combined" solutions, perhaps in combination with data from other space geodetic techniques (e.g. VLBI, GPS, GLONASS, DORIS, PRARE, etc.), in support of the IERS International Terrestrial Reference Frame (ITRF) or precise orbit determination. Organizations with the desire of eventually becoming Analysis Centers may also be designated as Associate Analysis Centers by the Governing Board until they are ready for full scale operation.

2.4.3 Lunar Analysis Centers

Lunar Analysis Centers process normal point data from the Lunar Laser Ranging (LLR) stations and generate a variety of scientific products including precise lunar ephemerides, librations, and orientation parameters which provide insights into the composition and internal makeup of the Moon, its interaction with the Earth, tests of General Relativity, and Solar System ties to the International Celestial Reference Frame.

2.5 Central Bureau

The Central Bureau (CB) is responsible for the daily coordination and management of the ILRS in a manner consistent with the directives and policies established by the Governing Board. The primary functions of the CB are to facilitate communications and information transfer within the ILRS and between the ILRS and the external scientific community, coordinate ILRS activities, maintain a list of satellites approved for tracking support and their priorities, promote compliance to ILRS network standards, monitor network operations and quality assurance of data, maintain ILRS documentation and databases, produce reports as required, and organize meetings and workshops.

Although the Chairperson of the Governing Board is the official representative of the ILRS to external organizations, the CB, consonant with the directives established by the Governing Board, is responsible for the day-to-day liaison with such organizations.

The CB coordinates and publishes all documents required for the satisfactory planning and operation of the Service, including standards/specifications regarding the performance, functionality and configuration requirements of all elements of the Service including user interface functions.

The CB operates the communication center for the ILRS. It produces and/or maintains a hierarchy of documents and reports, in both hard copy and electronic form, including network information, standards, newsletters, electronic bulletin board, directories, summaries of ILRS performance and products, and an Annual Report.

The Central Bureau may propose to the Governing Board names of individuals to be considered by the ILRS Associates for election as members at large to help ensure the proper representation of important contributing organizations.

The responsibilities and activities of the Central Bureau may be distributed between different groups and organizations according to written agreements and charters.

In summary, the Central Bureau performs a long term coordination and communication role to ensure that ILRS participants contribute to the Service in a consistent and continuous manner and that they adhere to ILRS standards.

The Central Bureau is headed by a Central Bureau Director, who is an ex-officio member of the ILRS Governing Board. The Secretary of the GB is also provided by the Central Bureau.

3.0 GOVERNING BOARD

3.1 Roles and Responsibilities

The Governing Board is responsible for the general directions in which the ILRS is providing its services. It defines the official ILRS products, decides upon the satellites to be included in the ILRS tracking list, accepts standards and procedures prepared and proposed by the individual bodies of the ILRS and ensures, through its chairperson, the contact to other services and organizations.

The GB exercises general control over the activities of the Service including modifications to the organization that would be appropriate to maintain efficiency and reliability, while taking full advantage of the advances in technology and theory.

Most GB decisions are to be made by consensus or by a simple majority vote of the members, provided that there is a quorum consisting of at least ten members of the GB. In case of lack of a quorum the voting is by mail or email. Changes in Terms of References and the Chairperson of the GB can be made by a 2/3 majority of the members of the GB, i.e., by twelve or more votes.

3.2 Membership

The Governing Board consists of both appointed and elected members. The appointed members include:

Director of the Central Bureau	1
Secretary of the Central Bureau	1
President of IAG Sect. II or Com.VIII (CSTG)	1

Members elected by their peers within the ILRS Associates include:

NASA SLR Network representatives	2
EUROLAS Network representatives	2
WPLTN Network representatives	2
Analysis and Associate Analysis Centers' representatives	2
Data centers' representative	1
LLR Representative	1
At-Large Members	2
IERS Representative	1
Total	16

The appointed members are considered ex-officio and are not subject to institutional restrictions. The elected board positions are nominated and elected by members of the ILRS components they represent for a two-year term. The At-Large members are intended to compensate for under-representation among the various components of the ILRS or to provide additional skills or knowledge of use to the Board in carrying out its duties. At-Large members are elected by the entire body of ILRS Associates. The total GB membership should be properly balanced in all respects with regard to supporting organizations, skill mix, geography, etc.

3.3 Nomination and Election of Members

ILRS Associate Members (see Section 4.1), together with the GB, may nominate and vote for the elected members of the GB. The Call for Nominations and GB Elections will be conducted by the Central Bureau via official email lists and will be held approximately every two years prior to the International Workshop on Laser Ranging. Newly elected GB members will be installed at the next semiannual meeting. With the exception of At-Large members, GB nominees must be associated with the relevant ILRS component (e.g. Analysis, Data Centers, Lunar, etc.), and only ILRS Associate Members officially associated with that component, as determined by the official email lists maintained by the CB, may participate in the election of their representative. The full ILRS membership can vote for At-Large members. The GB will be final arbiter on an individual's qualifications for a particular elected post on the Board. Election is by a simple majority of votes received. In the unlikely event of a tie vote, the GB will make the final selection in Executive Session.

3.4 Election and Role of Chairperson

The GB Chairperson is elected by the Board from among its members for a term of two years, renewable for three terms. Nomination and selection of the Chairperson is carried out in GB Executive Session during the biannual Workshop Meeting. The Chairperson does not vote, except in case of a tie. He/she is the official representative of the ILRS to external organizations.

3.5 Frequency of Meetings

The Board shall endeavor to meet semiannually and at such other times as shall be considered appropriate or opportune by the Chairperson or at the request of at least eight Governing Board members. Whenever possible and appropriate, the GB and CB will jointly sponsor a General Assembly twice per year for the benefit of the ILRS Associates. The logistics (schedule, location, advertising, etc.) for the General Assembly are the responsibility of the CB.

3.6 Rights and Privileges of GB Members

Members of the GB shall become IAG Fellows with the appropriate rights and privileges following two years of recognized service.

3.7 Analysis and Lunar Coordinators

The laser ranging technique is a broad based one. As an observational technique, the division between lunar laser ranging and artificial satellite laser ranging has become largely a historical one. However, present differences in many areas related to observations (e.g., predictions and data formats) are still being reconciled. It must also be recognized that the major data analysis packages that are presently used for artificial satellite analysis are not yet equipped to deal with lunar laser ranging observations and most of the LLR analysis packages are equally not yet compatible with SLR observations. Thus, it is prudent to maintain separate LLR and SLR coordinators for an, as yet, undefined time into the future. The SLR and LLR coordinators must work within their own disciplines to maintain observational and data integrities. However, they must also work together in an effort to unify both techniques, bringing together the best of both, and, when possible, learning from the other.

The Analysis and Lunar Coordinators are elected by the GB from its own membership and serve as the two voting ILRS representatives on the IERS Directing Board. The IERS in turn designates a representative to serve as an ex-officio voting member of the ILRS Governing Board.

The Analysis Coordinator is a voting member of the ILRS Governing Board and is elected by the Governing Board as the ILRS representative to the IERS Directing Board. Under a reciprocal arrangement, the IERS designates a representative to serve as a voting member on the ILRS Governing Board. The Lunar Coordinator may represent the ILRS as a deputy voting member on the IERS Directing Board in the Analysis Coordinator's absence and may otherwise attend IERS Board meetings at their discretion in a non-voting advisory capacity.

The Analysis Coordinator chairs the Analysis Working Group which includes, at a minimum, the Lunar Coordinator, one representative from each of the Global Analysis Centers and may contain representatives of Associate Analysis Centers as well.

The responsibility of the Analysis Coordinator is to monitor the Analysis Centers' activities to ensure that the ILRS objectives are carried out. Specific expectations include global data quality control, station performance evaluation and reporting, and continued development of appropriate analysis standards and formats for the final science products. The Analysis Coordinator is also responsible for the appropriate combination of designated Analysis Centers products into a single and coherent set of products.

The Analysis Coordinator ensures that the ILRS products produced by the ILRS Analysis and Associate Analysis Centers conform with IERS requirements and standards.

3.8 Working Groups

The Governing Board, at its discretion, can create or disband Working Groups. A Working Group (WG) may be either permanent (Standing) or temporary (Ad-Hoc) in nature. Standing Working Groups are created by the GB to carry out continuously evolving business of the ILRS. Occasionally, Ad-Hoc Working Groups are appointed to carry out special investigations or tasks of a temporary or interdisciplinary nature.

The valid activities for the various Working Groups are defined by their Charters. Modifications to the charters of existing WG's can be submitted by the corresponding Coordinator for approval by the Governing Board. In order to create a new WG, the sponsor must submit a proposed charter, which clearly states the goals and responsibilities of the new group, for approval by the GB.

The Coordinator of each Standing WG is selected by the GB from amongst its members to ensure close coupling of the WG with the GB and its goals. The WG Coordinator can independently appoint additional members to the WG from among the other GB members, ILRS Associate Members or ILRS Correspondents (see below). The WG Coordinator may also designate a Deputy to act on his/her behalf in his/her absence. All GB members, with the exception of the ex-officio members and the Chairperson, are required to serve on at least one of the Standing Working Groups.

The Coordinator for Ad-Hoc Working Groups may be chosen, at the discretion of the Board, from outside its membership in order to best fulfill the goals of that WG.

Currently, the Standing Working Groups are:

- Missions
- Data Formats and Procedures
- Networks and Engineering
- Analysis

4.0 DEFINITIONS

4.1 ILRS Associate Members

Persons affiliated with recognized ILRS institutions and who routinely participate in any of the ILRS activities (management, missions, tracking, engineering, operations, data analysis, archiving, etc.) are eligible to be ILRS Associate Members. To gain official membership in the ILRS, an approved ILRS institution must submit the person's name, email, and primary ILRS function in the organization to the Central Bureau. ILRS Associate Members do not have to be employed by their institution sponsor; they merely need to provide a recognized ILRS-related service to the sponsoring institution under a contractual or cooperative arrangement. The Associate's stated function will determine his/her eligibility to nominate and/or vote for specific GB representatives as described in Section 3.3.

Associate Members may attend open (non-executive) ILRS meetings which are announced to the general community by the CB, place nominations for elected GB posts, vote in ILRS elections, and serve on the Governing Board if appointed or elected. A directory, electronic and/or hard copy, of ILRS Associate Members, and their approved association with a particular component of the ILRS, is maintained by the CB.

ILRS Associate Members are considered IAG Affiliates with the corresponding rights and privileges.

4.2 ILRS Correspondents

ILRS Correspondents are persons on a mailing list maintained by the Central Bureau, who do not actively participate in the ILRS but who either express interest in receiving ILRS publications, wish to participate in workshops or scientific meetings organized by the ILRS, or generally are interested in ILRS activities. Ex-officio ILRS Correspondents are the following persons:

- IAG General Secretary
- President of IAG Section V

8.2 ILRS Website Map

ILRS Home Page at NASA in the USA
mirrored sites at EDC in Germany and CRL in Japan

About the ILRS
° Terms of Reference
° ILRS Bibliography°
° Central Bureau
° Governing Board
° History
° Join the ILRS
° Meetings
° Network Map
° Organization Chart
° Acronyms

Mail Services
° SLRMail
° SLReport
° URGENT
° ILRSPred
° ILRS Exploders

Contact the ILRS
° Directory of Associates
° Associate Locator

Working Groups (WG)
° **Analysis**
° °°Activities and Meetings
°°° Pilot Projects
°°° Actions
°°° Charter
°°° Members & Exploder
° **Networks and Engineering**
°°° Activities and Meetings
°°° Actions
°°° Charter
°°° Members & Exploder
° DF&P WG Charter
° DF&P WG Members
° DF&P WG Activities
° LEO Rapid Predictions
° Missions WG Charter
° Missions WG Members
°°Misisons WG Activities
° SP (Tiger) WG Charter
° SP (Tiger) WG Members
°°SP (Tiger) WG Activities
° Refraction Study Group Activities

Satellite Missions
° Campaign/Mission News
° Campaign Reports
° List of Missions
° Mission Analysis Reports
° Mission Parameters
° Mission Support History
° Priorities
° Request Tracking Support
° Link Budget Calculations

Stations
° Configurations
° Contacts
° Coordinates
° Data Anomalies
° DOMES Procedure
° Eccentricity Database
° Network Map
° News
° Site Pressure Profiles
° Site Identifiers
° Site Log Database
° Site Log Procedure
° Site Log Search Feature
° SOD Procedure
° Status Reporting
° System Performance

Products/Formats/Procedures
° **Normal Points** (NP)
°°°°°NP Availability
°°°°°NP Transmission Procedures
°°°°°NP Data Flow (table)
°°°°°NP Format Overview
°°°°°NP Format
°°°°°NP Algorithm
°°°°°NP Format/Data Integrity QC
° **Predictions**
°°°° Prediction Availability
°°°° Prediction Centers
°°°° Prediction Types
°°°° TIRV Format
°°°° TIRV Force Models
°°°° Maneuver Notification
°°°° Drag Function
°°°° Time Bias Function
°°**Fullrate** (FR)
°°°°°FR Availability
°°°°°FR Format
° **Site Positions and Velocities**
°°°° SLR Coordinates(ITRF2000)
°°°° SLR Coordinates(text file)
°°°° ILRS Sinex Description
° **Data Flow** (NP and Predictions)
°

Science/Analysis
° ILRS Bibliography
°IERS Conventions (1996 and 2000)
° Analysis Centers
°°Analysis Data Products
°°Mission Analysis Reports
°°ITRF Yearly Solutions
° SLR and Earth Science
° Science meetings

Engineering/Technology
° Collocation Results
° Performance Evaluation
° SLR Applications
°°SLR Animation
° Link Budget Calculations

Reports
° Analysis Reports
°°Bulletins
°°Campaign Reports
° ILRS Bibliography°
°°ILRS Meetings Reports
° Laser Workshop Reports
° Performance Report Cards
°°SLR/LLR CSTG Reports
° SLReport
°°Special Reports
°°Station Data Anomalies
° Station Status Reports

What's New
° Campaign/Missions News
° Meetings News
° Station News

Links
° Agencies
° Altimetry
° Analysis Centers
° Data Centers
° Earthquake/Tectonics
° Earth Rotation
° El Ni o and La Ni a
° Geodetic Services
° Gravity Models
° Laser Safety
° Missions
° Stations
° Useful
° Y2K

8.3 Network Performance Report Card for 2001

	Data Volume									
Location	Station Number	LEO Pass Total	LAG Pass Total	High Pass Total	Pass Total	LEO NP Total	LAGEOS NP Total	High NP Total	Total NP	Minutes of Track
Baseline		1000	400	100	1500					
Golosiiv	1824	349	100	0	449	5153	627	0	5780	2855.83
Maidanak 1	1863	16	15	5	36	202	99	33	334	430.25
Maidanak 2	1864	12	13	18	43	142	108	60	310	570.75
Komsomolsk	1868	63	20	14	97	884	130	54	1068	829.25
Mendeleevo	1870	249	0	0	249	2261	0	0	2261	711
Simeiz	1873	435	92	1	528	5073	556	4	5633	2711.33
Riga	1884	769	135	0	904	15935	1524	0	17459	7347.08
Katsively	1893	230	90	13	333	3939	782	70	4791	3205.92
McDonald	7080	2149	714	671	3534	28731	6191	2576	37498	34384.4
Yarragadee	7090	3850	1172	1380	6402	65967	14406	10640	91013	103167
Greenbelt	7105	4407	961	432	5800	83402	10837	3206	97445	65595.5
Monument Peak	7110	4586	878	533	5997	74923	9218	4242	88383	64843.3
Tahiti	7124	207	34	0	241	2996	307	0	3303	1728
Haleakala	7210	946	280	280	1506	11889	2932	1706	16527	18301.3
Wuhan	7231	6	3	0	9	80	34	0	114	100.5
Changchun	7237	2532	509	323	3364	41783	4905	2348	49036	35265.6
Beijing	7249	1130	194	50	1374	15663	1700	300	17663	10218.9
Kashima	7335	73	12	6	91	982	130	30	1142	788.167
Tateyama	7339	460	79	27	566	5539	517	130	6186	3692.25
Urumqi	7355	31	44	2	77	466	606	15	1087	1409.25
Lhasa	7356	102	117	12	231	1503	1410	51	2964	3609.75
Arequipa	7403	1619	257	0	1876	24779	2553	0	27332	13607.8
Hartebeesthoek	7501	1679	559	329	2567	21756	7265	2783	31804	36433.8
Cagliari	7548	74	7	0	81	1205	48	0	1253	572.25
Metsahovi	7806	432	97	15	544	9072	1328	88	10488	5693.83
Zimmerwald	7810	2187	685	266	3138	35267	9091	2191	46549	41058.8
Borowiec	7811	443	247	19	709	7748	2868	71	10687	8432.33
Kunming	7820	671	258	124	1053	10153	2187	730	13070	11501
San Fernando	7824	1402	215	0	1617	22477	1341	0	23818	10105.2
Helwan	7831	140	0	0	140	1384	0	0	1384	457.25
Riyadh	7832	1067	501	178	1746	20380	6889	1511	28780	28317.5
Grasse	7835	3614	746	106	4466	79572	8505	845	88922	44938
Potsdam	7836	1276	252	31	1559	19065	2229	145	21439	10763.5
Shanghai	7837	1201	279	117	1597	17264	2498	750	20512	14622.8
Simosato	7838	1290	280	107	1677	26348	3243	670	30261	18795.4
Graz	7839	3640	722	636	4998	85763	10633	5538	101934	75351.6
Herstmonceux	7840	2795	985	454	4234	38818	12093	2556	53467	49519.9
Grasse (LLR)	7845	15	387	574	976	290	6698	3134	10122	29138.5
Mt. Stromlo	7849	3148	870	397	4415	37892	7589	2419	47900	41743.4
Matera (MLRO)	7941	112	107	27	246	2048	1235	172	3455	4078.5
Wettzell	8834	896	382	138	1416	14822	3853	760	19435	16633.3
totals		50303	13298	7285	70886	843616	149165	49828	1042609	823530

		Data Quality					Operational Compliance		
Location	Station Number	SS RMS	NP RMS	Short Term	Long Term	% of good LAGEOS NP	Data Latency (hours)	Format Revision	Site logs
Baseline			10	20	20	95	12	1	yes
Golosiiv	1824	78	14	88		32	19	1	yes
Maidanak 1	1863					0	120	1	no
Maidanak 2	1864	91	12	29		36	60	1	no
Komsomolsk	1868	142	32	27		58	156	1	no
Mendeleevo	1870						40	1	no
Simeiz	1873	71	21	42		33	15	0	yes
Riga	1884	14	5	20	15	91	2	1	yes
Katsively	1893	65	13	23		93	17	0	yes
McDonald	7080	12	3	13	2	99	1	1	yes
Yarragadee	7090	10	2	10	2	98	1	1	yes
Greenbelt	7105	10	2	11	3	98	2	1	yes
Monument Peak	7110	9	2	12	4	97	3	1	yes
Tahiti	7124	8	4	15		94		1	yes
Haleakala	7210	10	5	13	7	97	1	1	yes
Wuhan	7231								yes
Changchun	7237	15	6	21	8	98	1	1	yes
Beijing	7249	12	21	37	36	55	8	1	yes
Kashima	7335								yes
Tateyama	7339	13	3	19	15	91	2	1	yes
Urumqi	7355								yes
Lhasa	7356	31	8	24		85	13	1	yes
Arequipa	7403	7	3	17	5	99	3	1	yes
Hartebeesthoek	7501	10	2	13	7	99	3	1	yes
Cagliari	7548						23	0	yes
Metsahovi	7806	21	8	23	12	93	2	1	yes
Zimmerwald	7810	19	3	11	5	99	2	1	yes
Borowiec	7811	28	8	18	13	94	3	1	yes
Kunming	7820	36	6	37	29	65	2	0	yes
San Fernando	7824	18	4	38	80	24	2	1	yes
Helwan	7831						11	0	yes
Riyadh	7832	17	3	18	3	96	5	0	yes
Grasse	7835	17	2	10	2	99	3	1	yes
Potsdam	7836	17	6	17	8	96	7	1	yes
Shanghai	7837	16	6	29	14	89	2	1	yes
Simosato	7838	33	6	21	13	95	0	0	yes
Graz	7839	8	2	11	2	99	5	1	yes
Herstmonceux	7840	18	2	11	1	99	1	1	yes
Grasse (LLR)	7845	22	3	11	8	97	1	1	yes
Mt. Stromlo	7849	11	3	13	5	99	6	1	yes
Matera (MLRO)	7941	6	2	14		99	207	1	yes
Wettzell	8834	21	3	22	7	100	3	1	yes
totals									

8.4 ILRS NETWORK STATISTICS

Table 8.4-1. Low Orbiting Satellites

Site Name	Stat n	LRE	STR-3	CHMP	SNST	ERS-2	STAR.	STEL.	WEST.	GFO-1	BE-C	REFL.	MET-3M	Jason	TPX	Ajisai	Total
Arequipa	7403	0	0	24	0	148	250	195	18	132	228	0	0	0	282	344	1,621
Beijing	7249	0	0	18	0	73	172	97	15	61	175	0	0	0	243	276	1,130
Borowiec	7811	0	0	23	0	76	52	28	24	38	24	0	0	0	111	67	443
Cagliari	7548	0	0	0	0	7	7	2	0	8	3	0	0	0	13	34	74
Changchun	7237	0	1	53	0	169	401	195	52	178	347	0	0	0	601	536	2,533
Grasse	7835	0	0	201	0	466	477	383	228	346	404	0	0	0	684	421	3,610
Grasse	7845	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15
Graz	7839	0	1	134	0	393	539	421	209	316	434	0	0	0	662	531	3,640
Greenbelt (MOB-7)	7105	0	1	81	0	287	820	395	95	367	744	0	1	3	717	900	4,411
Haleakala	7210	0	1	15	0	91	120	121	41	90	158	0	0	0	140	169	946
Hartebeesthoek	7501	0	0	7	0	121	297	217	32	131	120	0	0	0	302	450	1,677
Helwan	7831	0	0	0	0	2	6	12	0	0	25	0	0	0	52	43	140
Herstmonceux	7840	0	0	127	0	292	422	327	174	260	176	0	0	0	548	471	2,797
Kashima	7335	0	0	2	0	7	8	7	2	8	4	0	0	0	7	28	73
Katzively	1893	0	0	1	0	42	27	18	2	26	22	0	0	0	37	55	230
Kiev	1824	0	0	2	0	48	40	19	17	54	29	0	0	0	86	54	349
Koganei	7328	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Komsomolsk	1868	0	0	0	0	0	14	1	0	1	12	0	0	0	19	16	63
Kunming	7820	0	0	0	0	8	76	57	0	20	147	0	0	0	158	205	671
Lhasa (TROS)	7356	0	0	0	0	2	7	14	0	5	10	0	0	0	28	36	102
Maidanak	1863	0	0	0	0	0	1	0	0	0	0	0	0	0	8	7	16
Maidanak	1864	0	0	0	0	1	1	0	0	0	0	0	0	0	5	5	12
Matera (MLRO)	7941	0	0	0	0	10	29	8	0	11	14	0	0	0	23	16	111
McDonald	7080	0	0	8	0	149	311	204	26	212	533	0	0	0	330	378	2,151
Mendeleevo	1870	0	0	0	0	48	11	35	16	45	0	0	0	0	54	40	249
Metsahovi	7806	0	0	42	0	80	27	58	5	75	3	0	0	0	79	63	432
Monument Peak	7110	0	2	56	0	298	719	398	128	318	941	0	2	1	655	1,069	4,587
Mount Stromlo	7849	0	0	115	0	191	760	352	65	131	2	0	0	0	610	923	3,149
Potsdam	7836	0	0	133	1	166	148	174	32	133	28	0	0	0	292	170	1,277
Riga	1884	0	0	95	0	164	61	67	0	125	0	0	0	0	163	94	769
Riyadh	7832	0	0	0	0	31	183	125	36	49	202	0	0	0	207	234	1,067
San Fernando	7824	0	0	54	0	103	239	151	2	69	226	0	0	0	243	317	1,404
Shanghai	7837	0	0	9	0	45	191	125	23	55	272	0	0	0	186	288	1,194
Simeiz	1873	0	0	10	0	45	45	17	0	54	49	0	0	0	110	106	436
Simosato	7838	0	0	1	0	88	220	101	15	85	250	0	0	0	223	307	1,290
Tahiti	7124	0	0	0	0	7	31	36	2	10	0	0	0	0	32	47	165
Tateyama	7339	0	0	4	0	16	76	42	9	12	103	0	0	0	62	136	460
Urumqi	7355	0	0	0	0	15	0	3	2	3	2	0	0	0	6	0	31
Wettzell	8834	0	0	0	0	30	147	68	1	37	98	0	0	0	268	247	896
Wuhan	7231	0	0	0	0	0	2	1	0	0	0	0	0	0	2	1	6
Yarragadee	7090	3	3	306	0	328	635	369	249	386	131	11	0	0	586	844	3,851
Zimmerwald	7810	0	0	46	0	172	359	249	85	148	265	0	0	0	442	421	2,187
Totals:	42 stations	18	9	1,567	1	4,219	7,931	5,092	1,605	3,999	6,181	11	3	4	9,276	10,350	50,266

Table 8.4-2. High Orbiting Satellites

Site Name	Statn	LAG1	LAG2	ETA-1	ETA-2	GPS35	GPS36	Moon	GL-75	GL-76	GL-77	GL-78	GL-80	GL-81	GL-82	GL-84	Total	Grand
	7403	149	154	0	0	0	0	0	0	0	0	0	0	0	0	0	303	1,924
Beijing	7249	112	85	13	11	0	0	0	0	0	0	15	0	0	0	10	246	1,376
Borowiec	7811	165	82	2	3	0	0	0	0	0	0	6	7	0	0	2	267	710
Cagliari	7548	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	8	82
Changchun	7237	262	248	43	60	0	0	0	4	5	6	56	65	10	8	66	833	3,366
Grasse	7835	429	317	12	19	6	2	0	0	0	0	18	28	0	0	21	852	4,462
Grasse	7845	225	162	132	119	123	100	298	0	0	0	20	87	0	0	60	1,326	1,341
Graz	7839	408	314	91	91	48	55	0	9	5	9	94	116	14	11	93	1,358	4,998
Greenbelt (MOB-7)	7105	645	553	105	114	14	15	0	0	0	0	187	230	0	0	103	1,966	6,377
Haleakala	7210	160	190	36	71	6	1	0	0	0	0	117	137	0	0	30	748	1,694
Hartebeesthoek	7501	352	436	129	132	2	1	0	0	0	0	219	146	0	0	81	1,498	3,175
Helwan	7831	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	140
Herstmonceux	7840	576	410	70	83	44	35	0	0	0	0	71	93	0	0	63	1,445	4,242
Kashima	7335	6	6	1	1	0	0	0	0	0	0	0	2	0	2	0	18	91
Katzively	1893	49	41	0	3	0	1	0	0	0	0	2	1	0	0	6	103	333
Kiev	1824	63	38	0	0	0	0	0	0	0	0	0	0	0	0	0	101	450
Koganei	7328	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Komsomolsk	1868	14	6	3	1	0	0	0	0	0	0	2	7	0	0	1	34	97
Kunming	7820	120	138	39	22	11	15	0	0	0	0	25	9	0	0	3	382	1,053
Lhasa (TROS)	7356	64	53	1	5	0	0	0	0	0	0	6	0	0	0	0	129	231
Maidanak	1863	9	6	0	1	0	1	0	0	0	0	0	3	0	0	0	20	36
Maidanak	1864	5	8	4	6	0	3	0	0	0	0	2	4	0	0	0	32	44
Matera (MLRO)	7941	77	48	6	4	4	3	0	0	0	0	10	11	0	0	0	163	274
McDonald	7080	345	424	134	135	51	58	144	0	0	0	76	109	0	0	55	1,531	3,682
Mendeleevo	1870	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	249
Metsahovi	7806	74	23	3	1	0	0	0	0	0	0	5	5	0	0	1	112	544
Monument Peak	7110	482	427	151	152	43	30	0	0	0	0	166	189	0	0	86	1,726	6,313
Mount Stromlo	7849	467	410	45	50	6	4	0	0	0	0	152	117	0	0	26	1,277	4,426
Potsdam	7836	153	99	0	2	0	0	0	0	0	0	7	15	0	0	7	283	1,560
Riga	1884	89	47	0	0	0	0	0	0	0	0	0	0	0	0	0	136	905
Riyadh	7832	244	257	24	19	34	23	0	0	0	0	29	31	0	0	22	683	1,750
San Fernando	7824	115	101	0	0	0	0	0	0	0	0	0	0	0	0	0	216	1,620
Shanghai	7837	138	137	12	17	0	0	0	3	1	3	0	32	7	6	34	390	1,584
Simeiz	1873	45	47	0	0	0	0	0	0	0	0	1	0	0	0	0	93	529
Simosato	7838	135	145	25	20	0	0	0	0	0	0	17	25	0	0	20	387	1,677
Tahiti	7124	14	11	0	0	0	0	0	0	0	0	0	0	0	0	0	25	190
Tateyama	7339	45	34	4	5	1	0	0	0	0	0	8	6	0	3	0	106	566
Urumqi	7355	42	3	0	1	0	0	0	0	0	0	1	0	0	0	0	47	78
Wettzell	8834	203	191	26	28	5	0	0	0	0	0	32	31	0	0	17	533	1,429
Wuhan	7231	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	9
Yarragadee	7090	596	585	294	318	279	223	0	0	0	0	459	354	0	0	283	3,391	7,242
Zimmerwald	7810	390	296	44	38	23	19	0	0	0	0	6	72	0	0	63	951	3,138
Totals:	42 stations	7,473	6,537	1,449	1,532	700	589	442	16	11	18	1,809	1,932	31	30	1,153	23,722	73,988

8.5 ILRS NETWORK COLLOCATION

Site Name	Country	Lat.	E. Lon.	Laser SOD	Laser DOMES	GPS	GLONASS	VLBI	DORIS	PRARE	Gravi-meter
Arequipa	Peru	-16¡ 28’	-71¡ 38’	74031303	42202M003	AREQ			AREB		
Beijing	China	39¡ 55’	116¡ 25’	72496101	21601S004	BJFS					Absolute
Borowiec	Poland	52¡ 17’	17¡ 05’	78113802	12205S001	BOR1	BORG				Absolute
Cagliari	Italy	39¡ 08’	08¡ 58’	75486201	12725S013	CAGL					
Changchun	China	43¡ 50’	125¡ 20’	72371901	21611S001						
Grasse	France	43¡ 45’	06¡ 55’	78353102	10002S001	GRAS					Absolute
Grasse	France	43¡ 45’	06¡ 55’	78457801	10002S002	GRAS					Absolute
Graz	Austria	47¡ 04’	15¡ 30’	78393402	11001S002	GRAZ	GRAB				Absolute
Greenbelt	USA	39¡ 01’	-76¡ 50’	71050725	40451M105	GODE	GODZ	GGAO7108	GREB	Yes	
Haleakala	USA	20¡ 43’	-156¡ 16’	72102313	40445M001	MAUI					
Hartebeesthoek	South Africa	-25¡ 53’	27¡ 42’	75010602	30302M003	HARB, HRAO		HARTRAO	HBKB	Yes	
Helwan	Egypt	29¡ 52’	31¡ 21’	78314601	30101S001						
Herstmonceux	United Kingdom	50¡ 52’	00¡ 20’	78403501	13212S001	HERS	HERP				
Kashima	Japan	35¡ 57’	140¡ 40’	73357201	21701M002	KSMV		KASHIM11, KASHIM34			
Katzively	Ukraine	44¡ 23’	33¡ 58’	18931801	12337S006						
Kiev	Ukraine	50¡ 22’	30¡ 30’	18248101	12356S001	GLSV					
Koganei	Japan	35¡ 43’	139¡ 29’	73287101	21704M001	KGNO, KGNI		KOGANEI			
Komsomolsk	Russia	50¡ 52’	136¡ 59’	18685901	12341S001						
Kunming	China	25¡ 04’	102¡ 41’	78208201	21609S002	KUNM					Yes
Lhasa (TROS)	China	29¡ 25’	91¡ 07’	73568401	21613M003	LHAS	LHAZ				
Maidanak	Uzbekistan	38¡ 41’	66¡ 56’	18635101	12340S001						
Maidanak	Uzbekistan	38¡ 41’	66¡ 56’	18645401	12340S002						
Matera (MLRO)	Italy	40¡ 39’	16¡ 42’	79417701	12734S008	MATE	MAT1	MATERA		Yes	
McDonald	USA	30¡ 41’	-104¡ 01’	70802419	40442M006	MDO1		FD-VLBA			
Mendeleevo	Russia	56¡ 02’	37¡ 14’	18706301	12309S001	MDVO	MDVJ				
Metsahovi	Finland	60¡ 13’	24¡ 24’	78067601	10503S014	METS	METZ		METB		Superconducting
Monument Peak	USA	32¡ 53’	-116¡ 25’	71100411	40497M001	MONP					
Mount Stromlo	Australia	-35¡ 19’	149¡ 01’	78498001	50119S001	STR1	STR2		MSOB		Superconducting
Potsdam	Germany	52¡ 23’	13¡ 04’	78365801	14106S009	POTS					
Riga	Latvia	56¡ 53’	24¡ 08’	18844401	12302S002						Absolute
Riyadh	Saudi Arabia	24¡ 41’	46¡ 42’	78325501	20101S001						
San Fernando	Spain	36¡ 28’	-06¡ 12’	78244502	13402S007	SFER					
Shanghai	China	31¡ 11’	121¡ 26’	78372805	21605S001	SHAO		SESHAN25			
Simeiz	Ukraine	44¡ 16’	33¡ 36’	18734901	12337S003						
Simosato	Japan	33¡ 34’	135¡ 56’	78383602	21726S001						
Tahiti	French Polynesia	-17¡ 35’	-149¡ 37’	71240802	92201M007	THTI			PAQB	Yes	
Tateyama	Japan	35¡ 56’	139¡ 51’	73397401	21740M001			TATEYAMA			
Urumqi (TROS)	China	43¡ 43’	87¡ 38’	73558401	21612M002	URUM		URUMQI			
Wettzell	Germany	49¡ 09’	12¡ 53’	88341001	14201S018	WTZA, WTZR, WTZT	WTZJ, WTZZ	WETTZELL			Superconducting
Wuhan	China	30¡ 35’	114¡ 19’	72312901	21602S004	WUHN					Supercon. and Abs.
Yarragadee	Australia	-29¡ 03’	115¡ 21’	70900513	50107M001	YAR1, YAR2	YARR		YARB		
Zimmerwald	Switzerland	46¡ 53’	07¡ 28’	78106801	14001S007	ZIMM	ZIMJ, ZIMZ				Earth Tide
Totals:					42	31	12	10	7	4	12

Note: This table reflects current co-locations as of 31-Dec-2001

8.6 ILRS COMPONENTS

ILRS Central Bureau

NASA Goddard Space Flight Center (GSFC), USA

Global Data Centers

Crustal Dynamics Data Information System (CDDIS), NASA GSFC, USA
EUROLAS Data Center (EDC), Deutsches Geod tisches ForschungsInstitut (DGFI), Germany

Regional Data Centers

Shanghai Observatory, Academia Sinica, China

Operations Center

Russian Mission Control Center (MCC), Russia
University of Texas at Austin, Center for Space Research (CSR), USA
NASA Goddard Space Flight Center (NASA GSFC), USA
University of Texas at Austin, USA

Analysis Centers

Delft University of Technology (DUT), The Netherlands
Russian Mission Control Center (MCC), Russia
University of Texas at Austin, Center for Space Research (CSR), USA

Lunar Analysis Centers

Observatoire de Paris, France
Forschungseinrichting Satellitengeod sie (FESG), Germany
Jet Propulsion Laboratory (JPL), USA
University of Texas at Austin, USA

Associate Analysis Centers

Austrian Academy of Sciences, Austria
Australian Surveying and Land Information Group (AUSLIG), Australia
Academia Sinica, China
Observatoire de la C te d'Azur/Centre d'Etudes et de Recherches G odynamiques et Astrom trie (OCA/CERGA), France
Bundesamt f r Kartographie und Geod sie (BKG), Germany
Central Laboratory for Geodesy, Bulgarian Academy, Bulgaria
Communications Research Laboratory (CRL), Japan
Deutsches Geod tisches ForschungsInstitut (DGFI), Germany
European Space Agency/ESA Space Operations Center (ESA/ESOC), Germany
GeoForschungsZentrum, Germany
Agenzia Spaziale Italiana/Centro de Geodesia Spaziale (ASI/CGS), Italy
Forsvarets ForskningsInstitutt (FFI, sNorwegian Defence Research Establishment), Finland
Institute of Applied Astronomy, Russia
Institute of Astronomy of the Russian Academy of Sciences, Russia
Institute of Metrology for Time and Space, Russia
Astronomical Institute, University of Berne (AIUB), Switzerland
Main Astronomical Observatory of the National Academy of Sciences of the Ukraine (GAOUA), Ukraine
National Space Development Agency (NASDA), Japan
Natural Environment Research Council, United Kingdom
University of Newcastle, United Kingdom
NASA Goddard Space Flight Center (GSFC), USA

8.7 ILRS Organizations

Agency	Country
Geosciences Australia/National Mapping Division (GA/NMD)	Australia
Division of National Mapping/Geodesy Section	Australia
Austrian Academy of Sciences	Austria
Central Laboratory for Geodesy, Bulgarian Academy	Bulgaria
Academia Sinica	China
Chinese Academy of Surveying and Mapping	China
State Seismological Bureau	China
Yunnan Observatory	China
Technical University of Prague	Czech Republic
National Research Institute of Astronomy and Geophysic (NRIAG)	Egypt
Finnish Geodetic Institute	Finland
Observatoire de la C te d'Azur/Centre d'Etudes et de Recherches G odynamiques et Astrom trie (OCA/CERGA)	France
Observatoire de Paris	France
Tahiti Geodetic Observatory, University of French Polynesia (UFP)	French Polynesia
Bundesamt f r Kartographie und Geod sie (BKG)	Germany
Deutsches Geod tisches ForschungsInstitut (DGFI)	Germany
European Space Agency (ESA)	Germany
Forschungseinrichting Satellitengeod sie (FESG)	Germany
GeoForschungsZentrum (GFZ)	Germany
Technical University of Munich	Germany
University of Hannover/Institut fuer Erdmessung	Germany
Indian Space Research Organization (ISRO) Telemetry Tracking and Command Network (ISTRAC)	India
Astronomical Observatory of Cagliari	Italy
Italian Space Agency (ASI)	Italy
Communications Research Laboratory (CRL)	Japan
Hydrographic Department/Japan Coast Guard	Japan
National Space Development Agency (NASDA)	Japan
Astronomical Observatory, University of Latvia	Latvia
Division for Electronics, Forsvarets ForskningsInstitutt (FFI)	Norway
Universidad Nacional de San Augustin (UNSA)	Peru
Space Research Centre of the Polish Academy of Sciences (PAS)	Poland
Institute of Applied Astronomy (IAA)	Russia
Institute of Astronomy of the Russian Academy of Sciences (INASAN)	Russia
Institute of Metrology for Time and Space (IMVP)	Russia
Mission Control Centre (MCC)	Russia
Russian Space Agency (RSA)	Russia
Space Research Insitute (SRI) for Precision Instrument Engineering	Russia
King Abdulaziz City for Science and Technology (KACST)	Saudi Arabia

Agency	Country
Hartebeesthoek Radio Astronomy Observatory (HartRAO)	South Africa
Real Instituto y Observatorio de la Armada	Spain
Astronomical Institute, Unversity of Berne (AIUB)	Switzerland
Delft University of Technology (DUT)	The Netherlands
Crimean Astronomical Observatory	Ukraine
Lebedev Physical Institute in the Crimea	Ukraine
Main Astronomical Observatory (MAO) of the National Academy of Sciences of Ukraine	Ukraine
Natural Environment Research Council (NERC)	United Kingdom
University of Newcastle Upon Tyne	United Kingdom
Harvard-Smithsonian Center for Astrophysics	USA
Jet Propulsion Laboratory (JPL)	USA
National Aeronautics and Space Administration Goddard Space Flight Center (NASA GSFC)	USA
Naval Center for Space Technology (NCST)	USA
University of Hawaii	USA
University of Texas at Austin	USA
University of Texas, Center for Space Research (CSR)	USA

8.8 ILRS Associates and Correspondents

ILRS Assosciates

Name	Organization	Country	E-Mail
Igors Abakumovs	Astronomical Institute, University of Latvia	LATVIA	riglas@lanet.lv
Abd EL Rohman Ahmed	NRIAG	EGYPT	nriag@frcu.eun.eg
Fahad Al-Zaaydey	KACST/Institute of Space Research	SAUDI ARABIA	salro@kacst.edu.sa
Jun Amagai	Communications Research Laboratory	JAPAN	amagai@crl.go.jp
Dr. Per Helge Andersen	Division for Electronics (FFI)	NORWAY	per-helge.andersen@ffi.no
Dr.-Ing. Detlef Angermann	DGFI/Abt. 1	GERMANY	angerman@dgfi.badw.de
Graham Appleby	ITE Monks Wood	UNITED KINGDOM	gapp@mail.nerc-monkswood.ac.uk
Helmy Awad	NRIAG	EGYPT	nriag@frcu.eun.eg
Attalla EL Azab	NRIAG	EGYPT	nriag@frcu.eun.eg
Dr. Aldo Banni	Astronomical Observatory of Cagliari	ITALY	banni@ca.astro.it
Louis Barendse	Hartebeesthoek Radio Astronomy Observatory	SOUTH AFRICA	louis@hartrao.ac.za
Peter Bargewell	MOBLAS-5	AUSTRALIA	moblas@midwest.com.au
Dr. Francois Barlier	CERGA/GRGS	FRANCE	francois.barlier@obs-azur.fr
Jacek Bartoszak	Space Research Center of the PAS	POLAND	laser@cbk.poznan.pl
Gerald Baustert	GeoForschungsZentrum Potsdam	GERMANY	gbau@gfz-potsdam.de
Cheng Behui	Beijing Station	CHINA	bjslr@casm.ac.cn
David Benham	NERC Space Geodesy Facility	UNITED KINGDOM	slr@slrb.rgo.ac.uk
Johan Bernhardt	Hartebeesthoek Radio Astronomy Observatory	SOUTH AFRICA	johan@hartrao.ac.za
Prof. Gerhard Beutler	Astronomical Institute, University of Berne	SWITZERLAND	gerhard.beutler@aiub.unibe.ch
Dr. Richard Biancale	CNES/GRGS	FRANCE	richard.biancale@cnes.fr
Dr. Giuseppe Bianco	Agenzia Spaziale Italiana (ASI)	ITALY	giuseppe.bianco@asi.it
Patrick Bidart	Observatoire de Paris	FRANCE	patrick.bidart@obspm.fr
Matthew Bieneman	HTSI/SLR	USA	matthew.bieneman@honeywell-tsi.com
Maceo Blount	MOBLAS-7/c/o HTSI SLR	USA	maceo.blount@honeywell-tsi.com
Armin Boer	BKG, Fundamentalstation Wettzell	GERMANY	boer@wettzell.ifag.de
Dale H. Boggs	JPL/Mail Stop 238-332	USA	dale.boggs@jpl.nasa.gov
Pascal Bonnefond	OCA/CERGA/GRGS	FRANCE	pascal.bonnefond@obs-azur.fr
Alain Bonneville	Institut de Physique du Globe	FRANCE	bonnevil@ipgp.jussieu.fr
Oscar L. Brogdon	HTSI/SLR	USA	oscar.brogdon@honeywell-tsi.com
Mark Broomhall	Remote Sensing & Satellite Research Grp.	AUSTRALIA	m.a.broomhall@curtin.edu.au
Franco Buffa	Stazione Astronomica di Cagliari	ITALY	fbuffa@ca.astro.it
Edward Butkiewicz	Space Research Center of the PAS	POLAND	ebut@cbk.poznan.pl
Randall Carman	MOBLAS-5	AUSTRALIA	moblas@midwest.com.au
David L. Carter	NASA GSFC, Code 920.1	USA	dlcarter@pop900.gsfc.nasa.gov
Tomasz Celka	Space Research Centre of PAS	POLAND	celka@cbk.poznan.pl
Javor Chapanov	Central Laboratory for Geodesy, Bulgarian Academy	BULGARIA	chapanov@bgcict.acad.bg
Jean Chapront	Observatoire de Paris	FRANCE	jean.chapront@obspm.fr
Michelle Chapront-Touze	Observatoire de Paris	FRANCE	michelle.chapront@obspm.fr
John W. Cheek	NASA GSFC, Code 299/Raytheon ITSS	USA	jcheek@pop900.gsfc.nasa.gov
Prof. Dr. Junyong Chen	Beijing Station	CHINA	jychen@sun.ihep.ac.cn
Dr. Minkang Cheng	U. of Texas, Center for Space Research	USA	cheng@csr.utexas.edu
Hunag Cheng	Shanghai Associate Analysis Center	CHINA	hc@center.shao.ac.cn
Christopher (Bart) Clarke	HTSI/SLR	USA	christopher.clarke@honeywell-tsi.com
Ludwig Combrinck	Hartebeesthoek Radio Astronomy Observatory	SOUTH AFRICA	ludwig@bootes.hartrao.ac.za
Etienne Cuot	CERGA	FRANCE	cuot@obs-azur.fr
Jose Martin Davila	Real Instituto y Observatorio Armada	SPAIN	mdavila@roa.es
Mark Davis	HTSI/SLR	USA	mark.davis@honeywell-tsi.com
George Davisson	HTSI/SLR	USA	george.davisson@honeywell-tsi.com
John Dawson	AUSLIG, Space Geodesy Analysis Center	AUSTRALIA	johndawson@auslig.gov.au
Dr. John J. Degnan	NASA GSFC, Code 920.3	USA	jjd@ltpmail.gsfc.nasa.gov
Dr. Roberto Devoti	Telespazio S.p.A.	ITALY	roberto.devoti@asi.it
Dr. Jean O. Dickey	JPL/Mail Stop 238-332	USA	jean.o.dickey@jpl.nasa.gov

Name	Organization	Country	E-Mail
Andrew I. Dmitrotsa	Simeiz Laser Station	UKRAINE	dmai@crao.crimea.ua
Buddy Donovan	HTSI/SLR	USA	howard.donovan@honeywell-tsi.com
Ted Doroski	MOBLAS-4	USA	m4mgr@slral2.honeywell-tsi.com
Dr. John M. Dow	European Space Agency	GERMANY	john.dow@esa.int
Dr. Hermann Drewes	DGFI/Dept. I	GERMANY	drewes@dgfi.badw.de
Dr. Maurice P. Dube	NASA GSFC, Code 920.1/Raytheon ITSS	USA	mdube@pop900.gsfc.nasa.gov
Peter J. Dunn	Raytheon ITSS	USA	peter_j_dunn@raytheon.com
Richard J. Eanes	U. of Texas, Center for Space Research	USA	eanes@csr.utexas.edu
Dieter Egger	Forschungseinrichtung Satellitengeodasie	GERMANY	dieter.egger@bv.tum.de
K. Elango	ISTRAC/ISRO	INDIA	elango@istrac.gov.in
Pierre Exertier	OCA/CERGA/GRGS	FRANCE	pierre.exertier@obs-azur.fr
Sami Fathallah	NRIAG	EGYPT	nriag@frcu.eun.eg
He-Sheng Feng	Yunnan Observatory	CHINA	yozsx@public.km.yn.cn
Qu Feng	Beijing Station	CHINA	bjslr@casm.ac.cn
Dominique Feraudy	CERGA/OCA/GRGS	FRANCE	feraudy@obs-azur.fr
Sergey V. Filikov	Simeiz Laser Station	UKRAINE	filikov@crao.crimea.ua
Dr. Harald Fischer	GeoForschungsZentrum Potsdam	GERMANY	fisch@gfz-potsdam.de
Beate Forberg	DGFI	GERMANY	edc@dgfi.badw-muenchen.de
Craig Foreman	LURE Observatory	USA	foreman@banana.ifa.hawaii.edu
Gerard Francou	Observatoire de Paris	FRANCE	francou@bdl.fr
Dr. Masayuki Fujita	Hydrographic Department/Japan Coast Guard	JAPAN	masayuki-fujita@kaiho.mlit.go.jp
Dr. Yang Fumin	Shanghai Observatory/Academia Sinica	CHINA	yangfm@center.shao.ac.cn
Maurice Furia	OCA/CERGA	FRANCE	maurice.furia@obs-azur.fr
Yue Gao	EOS	AUSTRALIA	stromlo_slr@eos-aus.com
Jorge Garate	Real Instituto y Observatorio Armada	SPAIN	jgarate@roa.es
Katia Garceran	Tahiti Geodetic Observatory	FRENCH POLYNESIA	katia.garceran@upf.pf
David Gavin	Tahiti Geodetic Observatory	FRENCH POLYNESIA	david.gavin@upf.pf
Dr. Iskander Gayazov	Institute of Applied Astronomy	RUSSIA	gayazov@quasar.ipa.nw.ru
Gary Gebet	NASA Tracking Station/MOBLAS-4	USA	m4mgr@slral2.honeywell-tsi.com
Ivan Georgiev	Central Laboratory for Geodesy, Bulgarian Academy	BULGARIA	ivan@argo.bas.bg
Michael Gerstl	DGFI	GERMANY	gerstl@dgfi.badw-muenchen.de
Philip Gibbs	NERC Space Geodesy Facility	UNITED KINGDOM	slr@slrb.rgo.ac.uk
Monique Glentzin	OCA/CERGA	FRANCE	monique.glentzlin@obs-azur.fr
Vladimir D. Glotov	Russian Mission Control Centre (MCC)	RUSSIA	cnss@mcc.rsa.ru
Mariano Gomez	Avenida Parra Pasaje	PERU	t3mgr@unsa.edu.pe
Dr. Ramesh Govind	AUSLIG, Geodesy Unit	AUSTRALIA	rameshgovind@auslig.gov.au
Dr. Ben A. Greene	Western Pacific Laser Tracking Network	AUSTRALIA	stromlo_slr@eos-aus.com
Dr. Ludwig Grunwaldt	GeoForschungsZentrum Potsdam	GERMANY	grun@gfz-potsdam.de
Tangyong Guo	State Seismological Bureau	CHINA	whslr@public.wh.hb.cn
Dr. Werner Gurtner	Astronomical Institute, University of Berne	SWITZERLAND	werner.gurtner@aiub.unibe.ch
Dr. Karel Hamal	Technical University Prague/Dept. of Phys. Electronics	CZECH REPUBLIC	prochazk@troja.fjfi.cvut.cz
Kenny T. Harned	McDonald Observatory	USA	kh@ranger.as.utexas.edu
Hermann Hauck	BKG	GERMANY	hauck@ifag.de
Wilhelm Haupt	Hartebeesthoek Radio Astronomy Observatory	SOUTH AFRICA	wilhelm@hartrao.ac.za
Walter Hausleitner	Austrian Academy of Sciences	AUSTRIA	walter.hausleitner@oeaw.ac.at
Miaochan He	Yunnan Observatory	CHINA	yozsx@public.km.yn.cn
J. Michael Heinick	HTSI/SLR	USA	michael.heinick@honeywell-tsi.com
Mohamed EL Helali	NRIAG	EGYPT	nriag@frcu.eun.eg
Julie E. Horvath	HTSI/SLR	USA	julie.horvath@honeywell-tsi.com
Urs Hugentobler	Astronomical Institute, University of Berne	SWITZERLAND	urs.hugentobler@aiub.unibe.ch
Van S. Husson	HTSI/SLR	USA	van.husson@honeywell-tsi.com
Dr. Makram Ibrahim	NRIAG	EGYPT	nriag@frcu.eun.eg
Chongguo Jiang	Yunnan Observatory	CHINA	yozsx@public.km.yn.cn
Gary Johnston	Geodesy Section/Division of National Mapping	AUSTRALIA	garyjohnston@auslig.gov.au
Alain Journet	OCA/CERGA	FRANCE	alain.journet@obs-azur.fr
Dr. Klaus Kaniuth	DGFI	GERMANY	kaniuth@dgfi.badw-muenchen.de

Name	Organization	Country	E-Mail
Dr. Futaba Katsuo	Communications Research Laboratory	JAPAN	futaba@crl.go.jp
Dr. Mark Kaufman	IMPV	RUSSIA	mark@imvp.aspnet.ru
Rainer Kelm	DGFI	GERMANY	kelm@dgfi.badw-muenchen.de
Ruth Kennard	NASA GSFC, Code 922/Raytheon ITSS	USA	rkennard@pop900.gsfc.nasa.gov
Dr. Georg Kirchner	Austrian Academy of Sciences	AUSTRIA	kirchner@flubpc04.tu-graz.ac.at
Steve M. Klosko	Raytheon ITSS	USA	steven_m_klosko@raytheon.com
Dr. Rolf Koenig	GeoForschungsZentrum Potsdam	GERMANY	rolf.koenig@gfz-potsdam.de
Yuri L. Kokurin	Katzively Laser Station	UKRAINE	kokurin@clo.ylt.crimea.com
Ronald Kolenkiewicz	NASA GSFC, Code 926	USA	ronk@ltpmail.gsfc.nasa.gov
Dr. Georgy Krasinsky	Institute of Applied Astronomy	RUSSIA	kra@quasar.ipa.nw.ru
Jeff Kuhn	LURE Observatory	USA	kuhn@ifa.hawaii.edu
Dirk Kuijper	European Space Agency	GERMANY	dirk.kuijper@esa.int
Hiroo Kunimori	Communications Research Laboratory	JAPAN	kuni@crl.go.jp
Vladislav Kurbasov	Katzively Laser Station	UKRAINE	root@clo.ylt.crimea.com
Dr. Maurice Laplanche	OCA/CERGA	FRANCE	maurice.laplanche@obs-azur.fr
Valdis Laposhka	Astronomical Institute, University of Latvia	LATVIA	riglas@lanet.lv
Dr. Kasimirs Lapushka	Astronomical Institute, University of Latvia	LATVIA	riglas@lanet.lv
Dr. Jan Latka	Space Research Centre of PAS	POLAND	jkl@cbk.waw.pl
Olivier Laurain	OCA/CERGA	FRANCE	olivier.laurain@obs-azur.fr
Lesiba Ledwaba	Hartebeesthoek Radio Astronomy Observatory	SOUTH AFRICA	lesiba@hartrao.ac.za
Frank G. Lemoine	NASA GSFC, Code 926	USA	flemoine@ishtar.gsfc.nasa.gov
Bill Lindsey	LURE Observatory	USA	lindsey@banana.ifa.hawaii.edu
Danny Van Loon	Delft University of Technology	THE NETHERLANDS	vanloon@geo.tudelft.nl
Victor Lucano	Avenida Parra Pasaje	PERU	t3mgr@unsa.edu.pe
Dr. Vincenza Luceri	Telespazio S.p.A.	ITALY	cinzia.luceri@asi.it
Dr. John Mck. Luck		AUSTRALIA	jmckluck@optusnet.com.au
Vadim Lunev	Simeiz Laser Station	UKRAINE	simeiz@mail.ylt.crimea.com
Dr. Keitapu Maamaatuaiahuta	Tahiti Geodetic Observatory	FRENCH POLYNESIA	maamaatu@upf.pf
Mike Maberry	LURE Observatory	USA	maberry@hawaii.edu
Maki Maeda	National Space Development Agency	JAPAN	maeda.maki@nasda.go.jp
Dr. Zinovy Malkin	Institute of Applied Astronomy	RUSSIA	malkin@quasar.ipa.nw.ru
Jean-Francois Mangin	OCA/CERGA	FRANCE	mangin@obs-azur.fr
Anthony Mann	HTSI/SLR	USA	anthony.mann@honeywell-tsi.com
John Manning	AUSLIG, Geodesy Unit	AUSTRALIA	johnmanning@auslig.gov.au
Dr. Maria Mareyen	BKG	GERMANY	mamy@ifag.de
Franz-Heinrich Massmann	GFZ/D-PAF	GERMANY	fhm@gfz-potsdam.de
David J. McClure	HTSI/SLR	USA	david.mcclure@honeywell-tsi.com
Jan F. McGarry	NASA GSFC, Code 920.3	USA	jan.mcgarry@gsfc.nasa.gov
Dr. Mikhail Medvedskij	Ukraine Laser Station	UKRAINE	medved@mao.kiev.ua
Francois Mignard	OCA/CERGA	FRANCE	francois.mignard@obs-azur.fr
Oleg Minin	Simeiz Laser Station	UKRAINE	simeiz@mail.ylt.crimea.com
Vladimir Mitrikas	Russian Mission Control Centre	RUSSIA	geozup@cityline.ru
Piet Mohlabeng	Hartebeesthoek Radio Astronomy Observatory	SOUTH AFRICA	solly@hartrao.ac.za
Chris Moore	EOS Pty. Ltd.	AUSTRALIA	chris-moore@mail.com
Dr. Philip Moore	University of Newcastle	UNITED KINGDOM	philip.moore@ncl.ac.uk
William Moralo	Hartebeesthoek Radio Astronomy Observatory	SOUTH AFRICA	willy@hartrao.ac.za
Dr. Ing. Juergen Mueller	U. of Hannover/Institut fuer Erdmessung	GERMANY	mueller@ife.uni-hannover.de
Horst Mueller	DGFI/Abt. 1	GERMANY	horst.mueller@dgfi.badw.de
Leonardo Mureddu	Astronomical Observatory of Cagliari	ITALY	mureddu@ca.astro.it
Olga Nagornuk	Simeiz Laser Station	UKRAINE	simeiz@mail.ylt.crimea.com
Liu Nailing	Beijing Station	CHINA	bjslr@casm.ac.cn
Dr. Reinhart Neubert	GeoForschungsZentrum Potsdam	GERMANY	neub@gfz-potsdam.de
Dmitriy Neyachenko	Simeiz Laser Station	UKRAINE	simeiz@mail.ylt.crimea.com
Marisa Nickola	Hartebeesthoek Radio Astronomy Observatory	SOUTH AFRICA	marisa@hartrao.ac.za
Joelle Nicolas	OCA/CERGA	FRANCE	joelle.nicolas@obs-azur.fr
Carey E. Noll	NASA GSFC, Code 920.1	USA	carey.noll@gsfc.nasa.gov
Ron Noomen	Delft University of Technology	THE NETHERLANDS	ron.noomen@deos.tudelft.nl
Dr. Antonin Novotny	Technical University of Prague	CZECH REPUBLIC	novotny@troja.fjfi.cvut.cz
Vince Noyes	MOBLAS-5	AUSTRALIA	moblas@midwest.com.au

Name	Organization	Country	E-Mail
Dan Nugent	HTSI/SLR	USA	daniel.nugent@honeywell-tsi.com
Konstantin Nurutdinov	University of Newcastle	UNITED KINGDOM	konstantin.nurutdinov@ncl.ac.uk
Daniel J. O'Gara	University of Hawaii	USA	ogara@ifa.hawaii.edu
Thomas Oldham	HTSI/SLR	USA	thomas.oldham@honeywell-tsi.com
Toshimichi Otsubo	Communications Research Laboratory	JAPAN	otsubo@crl.go.jp
Jack Paff	MOBLAS-5	AUSTRALIA	moblas@midwest.com.au
Mr. Jocelyn Paris	OCA/CERGA	FRANCE	jocelyn.paris@obs-azur.fr
Dr. Natalia Parkhomenko	SRI for Precision Instrument Engineering	RUSSIA	natali@ricimi.msk.su
Richard Pastor	U. of Texas, Center for Space Research	USA	pastor@csr.utexas.edu
Donald Patterson	HTSI/SLR	USA	donald.patterson@honeywell-tsi.com
Dr. Matti Paunonen	Finnish Geodetic Institute	FINLAND	geodeet@csc.fi
Andris Pavenis	Astronomical Institute, University of Latvia	LATVIA	riglas@lanet.lv
Dr. Erricos C. Pavlis	NASA GSFC, Code 926/JCET-UMBC	USA	epavlis@helmert.gsfc.nasa.gov
Dr. Michael R. Pearlman	Harvard-Smithsonian Center for Astrophysics	USA	mpearlman@cfa.harvard.edu
Francis Pierron	Observatoire de la cote d'azur	FRANCE	francis.pierron@obs-azur.fr
Eugen Pop	Astronomical Institute, University of Berne	SWITZERLAND	eugen.pop@aiub.unibe.ch
Dr. Ivan Prochazka	Technical University of Prague	CZECH REPUBLIC	prochazk@troja.fjfi.cvut.cz
Xiang Qingge	Beijing Station	CHINA	bjslr@casm.ac.cn
Manuel Quijano	Real Instituto y Observatorio de la Armada	SPAIN	mquijano@roa.es
Jean-Claude Raimondo	GeoForschungsZentrum Potsdam	GERMANY	raimondo@gfz-potsdam.de
Dr. Christoph Reigber	GeoForschungsZentrum Potsdam	GERMANY	reigber@gfz-potsdam.de
Sergei Revnivych	Russian Mission Control Centre	RUSSIA	bulmon@podlipki.ru
Dr. Bernd Richter	BKG	GERMANY	richter@ifag.de
Randall L. Ricklefs	University of Texas at Austin	USA	rlr@astro.as.utexas.edu
Stephan Riepl	BKG, Fundamentalstation Wettzell	GERMANY	riepl@wettzell.ifag.de
John C. Ries	U. of Texas, Center for Space Research	USA	ries@csr.utexas.edu
Judit Ries	McDonald Observatory	USA	moon@astro.as.utexas.edu
Domenico Del Rosso	ASI/CGS "G. Colombo"	ITALY	domenico_delrosso@telespazio.it
Markus Rothacher	Technische Universitaet Muenchen	GERMANY	rothacher@bv.tum.de
Brian Rubery	MOBLAS-5	AUSTRALIA	moblas@midwest.com.au
Sergei P. Rudenko	GFZ, Division 1, Section 1.2	GERMANY	rudenko@gfz-potsdam.de
Dr. Magdy EL Saftawy	NRIAG	EGYPT	nriag@frcu.eun.eg
Masatoshi Saitoh	National Space Development Agency	JAPAN	saitoh.masatoshi@nasda.go.jp
Tarik Salim	NRIAG	EGYPT	nriag@frcu.eun.eg
Etienne Samain	OCA/CERGA	FRANCE	etienne.samain@obs-azur.fr
Mikio Sawabe	National Space Development Agency	JAPAN	sawabe.mikio@nasda.go.jp
Remko Scharroo	Delft University of Technology/DEOS	THE NETHERLANDS	remko.scharroo@deos.tudelft.nl
Francesco Schiavone	ASI/CGS	ITALY	laser@asi.it
Danuta Schillak	Space Research Centre of PAS	POLAND	danka@cbk.poznan.pl
Dr. Stanislaw Schillak	Space Research Centre of PAS	POLAND	sch@cbk.poznan.pl
Anja Schlicht	Fundamentalstation Wettzell	GERMANY	schlicht@wettzell.ifag.de
Dr. Wolfgang Schlueter	Fundamentalstation Wettzell	GERMANY	schlueter@wettzell.ifag.de
Roland Schmidt	GFZ/OP c/o DLR	GERMANY	rschmidt@gfz-potsdam.de
Dr. Ulrich Schreiber	Fundamentalstation Wettzell	GERMANY	schreiber@wettzell.ifag.de
Bruce R. Schupler	HTSI/VLBI	USA	bruce.schupler@honeywell-tsi.com
Dr. Bob E. Schutz	U. of Texas, Center for Space Research	USA	schutz@csr.utexas.edu
Dr. Cecilia Sciarretta	Telespazio S.p.A.	ITALY	cecilia.sciarretta@asi.it
Ron Sebeny	MOBLAS-4	USA	m4mgr@slral2.honeywell-tsi.com
Wolfgang Seemueller	DGFI/Abt. I	GERMANY	seemueller@dgfi.badw-muenchen.de
Arata Sengoku	Hydrographic Department/Japan Coast Guard	JAPAN	arata-sengoku@kaiho.mlit.go.jp
Dr. Victor Shargorodsky	SRI for Precision Instrument Engineering	RUSSIA	natali@ricimi.msk.su
Dr. Peter J. Shelus	University of Texas at Austin	USA	pjs@astro.as.utexas.edu
Robert Sherwood	NERC Space Geodesy Facility	UNITED KINGDOM	slr@slrb.rgo.ac.uk
Dr. Lazar Shtirberg	Simeiz Laser Station	UKRAINE	lazar@crao.crimea.ua
Nadia Shuygina	Institute of Applied Astronomy	RUSSIA	nvf@quasar.ipa.nw.ru
Diglio Simoni	HTSI/SLR	USA	diglio.simoni@honeywell-tsi.com
Dr. Andrew T. Sinclair		UNITED KINGDOM	atsinclair@aol.com
Dr. David E. Smith	NASA GSFC, Code 920	USA	dsmith@tharsis.gsfc.nasa.gov
Victoria Smith	NERC Space Geodesy Facility	UNITED KINGDOM	slr@slrb.rgo.ac.uk
Alain Spang	OCA/CERGA	FRANCE	alain.spang@obs-azur.fr

Name	Organization	Country	E-Mail
Jim Steed	Geodesy Section/Division of National Mapping	AUSTRALIA	jimsteed@auslig.gov.au
Charles Steggerda	HTSI/SLR	USA	charlie.steggerda@honeywell-tsi.com
Paul Stevens	HTSI/SLR	USA	paul.stevens@honeywell-tsi.com
Ray Stringfellow	HTSI/SLR	USA	ray.stringfellow@honeywell-tsi.com
Pieter Stronkhorst	Hartebeesthoek Radio Astronomy Observatory	SOUTH AFRICA	pieter@hartrao.ac.za
Akinobu Suzuki	National Space Development Agency	JAPAN	suzuki.akinobu@nasda.go.jp
Wang Tanquiang	Beijing Station	CHINA	bjslr@casm.ac.cn
Dr. Suriya K. Tatevian	Institute of Astronomy/RAS, Space Geodesy Dept.	RUSSIA	statev@inasan.rssi.ru
Jean-Marie Torre	CERGA/GRGS	FRANCE	torre@obs-azur.fr
Mark H. Torrence	Raytheon ITSS	USA	mtorrenc@geodesy2.gsfc.nasa.gov
Ken Tribble	HTSI/SLR	USA	kenneth.tribble@honeywell-tsi.com
Vladimir Tryapitsin	Katzively Laser Station	UKRAINE	root@clo.ylt.crimea.com
Takashi Uchimura	National Space Development Agency	JAPAN	uchimura@eoc.nasda.go.jp
Johannes Utzinger	Astronomical Institute, University of Berne	SWITZERLAND	johannes.utzinger@aiub.unibe.ch
Jorge Valverde	Avenida Parra Pasaje	PERU	t3mgr@unsa.edu.pe
Prof. Vladimir P. Vasiliev	SRI for Precision Instrument Engineering	RUSSIA	natali@ricimi.msk.su
Merle Vaughn	MOBLAS-4	USA	m4mgr@slral2.honeywell-tsi.com
Dr. Franco Vespe	ASI-Centro Geodesia Spaziale	ITALY	franco.vespe@asi.it
Gerard Vigouroux	OCA/CERGA	FRANCE	gerard.vigouroux@obs-azur.fr
Martin L. Villarreal	McDonald Observatory	USA	mv@ranger.as.utexas.edu
Herve Viot	OCA/CERGA	FRANCE	herve.viot@obs-azur.fr
Hoai Vo	HTSI/SLR	USA	hoai.vo@honeywell-tsi.com
Yannick Vota	Tahiti Geodetic Observatory	FRENCH POLYNESIA	yannick.vota@upf.pf
Wu Wang	Yunnan Observatory	CHINA	yozsx@public.km.yn.cn
Scott L. Wetzel	HTSI/SLR	USA	scott.wetzel@honeywell-tsi.com
Jerry Wiant	MLRS Laser Project	USA	jrw@astro.as.utexas.edu
Urs Wild	Swiss Federal Office of Topography	SWITZERLAND	urs.wild@lt.admin.ch
Dr. James G. Williams	JPL/Mail Stop 238-332	USA	james.williams@jpl.nasa.gov
Windell L. Williams	MLRS Laser Project	USA	ww@ranger.as.utexas.edu
Dr. Roger Wood	NERC Space Geodesy Facility	UNITED KINGDOM	rw@slrb.rgo.ac.uk
Chen Xianjun	Beijing Station	CHINA	bjslr@casm.ac.cn
Yaoheng Xiong	Yunnan Observatory	CHINA	yozsx@public.km.yn.cn
Manuel Yanyache	Avenida Parra Pasaje	PERU	t3mgr@unsa.edu.pe
Dr. Dmitry Yatskiv	Ukraine Laser Station	UKRAINE	dmy@mao.kiev.ua
Prof. Yaroslav S. Yatskiv	Main Astronomical Observatory	UKRAINE	yatskiv@mao.kiev.ua
Zhang Yian	Beijing Station	CHINA	bjslr@casm.ac.cn
Dr. Taizoh Yoshino	Communications Research Laboratory	JAPAN	yosh@crl.go.jp
Zhao You	Changchun Satellite Observatory	CHINA	
Thomas W. Zagwodzki	NASA GSFC, Code 920.3	USA	thomas.w.zagwodzki@gsfc.nasa.gov
Rene Zandbergen	European Space Agency	GERMANY	rene.zandbergen@esa.int
Stanislaw Zapasnik	Space Research Centre of PAS	POLAND	zapasnik@cbk.poznan.pl
Shuxin Zhang	Yunnan Observatory	CHINA	yozsx@public.km.yn.cn
Kiangming Zheng	Yunnan Observatory	CHINA	yozsx@public.km.yn.cn
Dr. A. Zhestkov	IMVP VNIIFTRI	RUSSIA	mark@imvp.aspnet.ru
Zhang Zhongping	Shanghai Data Center	CHINA	zzp@center.shao.ac.cn
Wei Zibin	Beijing Station	CHINA	bjslr@casm.ac.cn
Michail Zinkovsky	Russian Mission Control Centre	RUSSIA	bulmon@podlipki.ru

ILRS Correspondents

Name	Organization	Country	E-Mail
John M. Bosworth	Swales Aerospace	USA	jbosworth@swales.com
Patrick Ferrick	Town of Webb School	USA	ferrick@zebulon.telenet.net
Dr. Richard S. Gross	JPL/Mail Stop 238-332	USA	rsg@logos.jpl.nasa.gov
Matthew Hejduk	SenCom Corporation	USA	mhejduk@earthlink.net
Dr. John LaBrecque	NASA HQ, Code YSG	USA	jlabrecq@hq.nasa.gov
Gene H. McCall	HQ AFSPC/CN	USA	gene.mccall@peterson.af.mil
Dr. George Nicolson	Hartebeesthoek Radio Astronomy	SOUTH AFRICA	george@bootes.hartrao.ac.za
Dr. Axel Nothnagel	Geodetic Institute	GERMANY	nothnagel@uni-bonn.de
Amey Peltzer	Naval Center for Space Technology/Code 8123	USA	peltzer@ccf.nrl.navy.mil
John W. Robbins	Pope John XXIII National Seminary	USA	jrobbins@surfbest.net
Dr. William Scharpf	Naval Center for Space Technology/Code 8123	USA	scharpf@ncst.nrl.navy.mil
Michael Selden		USA	seldenmd@yahoo.com
Dr. Patrick Sillard	IGN/LAREG/ENSG	FRANCE	sillard@ensg.ign.fr
Dr. Eric C. Silverberg	U. of Texas, Center for Space Research	USA	ecsilverberg@att.net
Jim Slater	NIMA, GICS	USA	slaterj@nima.mil
Dr. Alexander Stadnik	Kharkov Military University	UKRAINE	alex_stadnik@yahoo.com
John Steadman	Club Starshine	CANADA	water@bmts.com
Daniela Thaller	Technische Universitaet Muenchen	GERMANY	daniela.thaller@bv.tum.de
Dr. Jan Vondrak	Astronomical Institute, Academy of Sciences	CZECH REPUBLIC	vondrak@ig.cas.cz
Robert Weber	Technical University of Vienna	AUSTRIA	rweber@luna.tuwien.ac.at
Sheng Yuan Zhu	GeoForschungsZentrum Potsdam	GERMANY	zhu@gfz-potsdam.de

8.9 List of Acronyms

AAC	Associate Analysis Center
AC	Air Conditioner
AC	Analysis Center
ACT	Australian Capital Territory
ADEOS	Advanced Earth Observing Satellite
AFSPC	Air Force Space Command (USA)
AGSO	Australian Geological Survey Organization
AGU	American Geophysical Union
AIUB	Astronomical Institute of Berne (Switzerland)
ALOS	Advanced Land Observing Satellite
AMU	Amplitude Measuring Unit
AO	Announcement of Opportunity
APD	Avalanche Photo Diode
APOLLO	Apache Point Observatory Lunar Laser Ranging Operation (USA)
APRGP	Asia-Pacific Regional Geodetic Project
APSG	Asia-Pacific Space Geodynamics Project
ASCII	American Standard Code for Information Interchange
ASI	Agenzia Spaziale Italiana (Italian Space Agency)
AUSLIG	Australian Surveying and Land Information Group
AVN	Allgemeine Vermessungs-Nachrichten (Germany)
AWG	Analysis Working Group
Az/El	Azimuth/Elevation
BE-C	Beacon Explorer C
BKG	Bundesamt f r Kartographie und Geod sie (Germany)
CAL/VAL	Calibration/Validation
CB	Central Bureau
CCD	Charged Coupled Device
CCR	Corner Cube Reflector
CDDIS	Crustal Dynamics Data Information System (USA)
CDP	Crustal Dynamics Project
CERGA	Centre d'Etudes et de Recherches G odynamiques et Astrom trie (France)
CF	Constant Fraction
CFA	Center for Astrophysics (USA)
CFD	Constant Fraction Discriminator
CGS	Centro de Geodesia Spaziale (Italy)
CHAMP	CHAllenging Mini-Satellite Payload
CIS	Conventional Inertial System
CLG	Central Laboratory for Geodesy (Bulgaria)
CMB	Core-Mantle Boundary
CNES	Centre National d'Etudes Spatiales (France)
CNS	Communication, Navigation, Surveillance (USA)
CODE	Center for Orbit Determination in Europe
COM	Center Of Mass
COSPAR	Committee on Space Research
CPU	Central Processing Unit
CRAO	Crimean Astrophysical Observatory (Ukraine)
CRDF	Civilian Research Development Foundation (USA)
CRL	Communications Research Laboratory (Japan)
C-SPAD	Compensated Single Photoelectron Avalanche Detector

CSR	Center for Space Research (USA)
CSRIFS	Combined Square Root Information Filter and Smoother
CSTG	International Coordination of Space Techniques for Geodesy and Geodynamics
DANOF	Department of Fundamental Astronomy of the Paris Observatory (France)
DEC	Digital Equipment Corporation
DEOS	Delft Institute for Earth-Oriented Space Research (The Netherlands)
DFPWG	Data Formats and Procedures Working Group
DGFI	Deutsches Geod tisches ForschungsInstitut (Germany)
DOD	Department of Defense (USA)
DOGS	DGFI Orbit and Geodetic Parameter Estimation System (Germany)
DOMES	Directory Of MERIT Sites
DORIS	Doppler Orbitography and Radiopositioning Integrated by Satellite
DTM	Digital Terrain Model
DUT	Delft University of Technology (The Netherlands)
DXO	Dual Crossover
EDC	EUROLAS Data Center (Germany)
EGS	European Geophysical Society
ELV	Expendable Launch Vehicle
ENVISAT	ENVIronmental SATellite
EOP	Earth Orientation Parameter
EOS	Electro Optical Systems (Australia)
ERS	European Remote Sensing Satellite
ESA	European Space Agency
ESE	Earth Science Enterprise (USA)
ESOC	ESA Space Operations Center (Germany)
ETS	Engineering Test Satellite
EU	European Union
EUROLAS	European Laser Consortium
FAA	Federal Aviation Administration (USA)
FAQ	Frequently Asked Question
FAO	Food and Agriculture Organization
FDR	Foundation for Research Development (South Africa)
FESG	Forschungseinrichting Satellitengeod sie (Research Facility for Space Geodesy, Germany)
FFI	Forsvarets ForskningsInstitutt (Norwegian Defense Research Establishment)
FGAN	Forschungsgesellschaft f r Angewandte Naturwissenschaften (Germany)
FR	Full Rate
FTLRS	French Transportable Laser Ranging System
FTP	File Transfer Protocol
G3OS	Three Global Observing Systems
GAOUA	Main Astronomical Observatory of the National Academy of Sciences of Ukraine
GAVDOS	GPS/Gravity Aided Vertical Determination and Oceanic Sea-level
GB	Gigabyte
GB	Governing Board
GCOS	Global Climate Observing System
GeoDAF	Geodetical Data Archive Facility (Italy)
GeodIS	Geodetic Information System (Germany)
GEOS	Geodetic and Earth Orbiting Satellite
GEOSAT	Geodesy Satellite
GFO	GEOSAT Follow-On (USA)

GFZ	GeoForschungsZentrum (Germany)
GGAO	Goddard Geophysical and Astronomical Observatory (USA)
GIS	Geographic Information System
GLAS	Geoscience Laser Altimeter System
GLI	Global Imager
GLONASS	Global Navigation Satellite System
GLONASS	Global’naya Navigatsionnay Sputnikovaya Sistema
GM	Gravity Model
GNP	Generic Normal Point Processing
GOCE	Gravity Field and Steady-state Ocean Circulation Explorer
GOOS	Global Ocean Observing System
GP-B	Gravity Probe B
GPS	Global Positioning System
GRACE	Gravity Recovery And Climate Experiment
GRGS	Groupe de Recherches de G od sie Spatiale (France)
GRL	Geophysical Research Letters
GSFC	Goddard Space Flight Center (USA)
GTOS	Global Terrestrial Observing System
GUTS	Global and High Accuracy Trajectory Determination System.
H2A/LRE	Laser Ranging Experiment
HARTRAO	Hartebeesthoek Radio Astronomy Observatory (South Africa)
HEO	High Earth Orbit
HOLLAS	Haleakala Laser Station (USA)
HP	Hewlett-Packard
HQ	Headquarters
HTSI	Honeywell Technology Solutions, Inc. (USA)
H/W	Hardware
IA/RAS	Institute of Astronomy/Russian Academy of Sciences
IAA	Institute of Applied Astronomy, Russia
IAG	International Association of Geodesy
IAPG	Institut f r Astronomische und Physikalische Geod sie (Germany)
IAU	International Astronomical Union
ICESat	Ice Cloud and Land Elevation Satellite
ICRF	International Celestial Reference Frame
ICRS	International Celestial Reference System
ICSU	International Council for Science
IERS	International Earth Rotation Service
IFE	Institut f r Erdmessung (Germany)
IGEX	International GLONASS Experiment
IGGOS	Integrated Global Geodetic Observing System
IGLOS-PP	International GLONASS Service Pilot Project
IGN	Institut Geographique National (France)
IGOS	Integrated Global Observing Strategy
IGS	International GPS Service for Geodynamics
ILP	International Lithosphere Programme
ILRS	International Laser Ranging Service
IMVP	Institute of Metrology for Time and Space (Russia)
INASAN	Institute of Astronomy of the Russian Academy of Sciences
INTAS	International Association for the promotion of co-operation with scientists from the New Independent States (NIS) of the former Soviet Union
IOC	Intergovernmental Oceanographic Commission

IRV	Inter-Range Vector
ISGN	Integrated Space Geodetic Network
ISRO	Indian Space Research Organization
ISTRAC	ISRO Telemetry Tracking and Command Network (India)
ITE	Institute of Terrestrial Ecology
ITRF	International Terrestrial Reference Frame
ITRS	International Terrestrial Reference System
ITSS	Raytheon Information Technology and Scientific Services (USA)
IUGG	International Union of Geodesy and Geophysics
IVS	International VLBI Service for Geodesy and Astrometry
JCET	Joint Center for Earth Systems Technology (USA)
JGM	Joint Gravity Model
JGR	Journal of Geophysical Research
JHD	Japanese Hydrographic Department
JPL	Jet Propulsion Laboratory (USA)
KACST	King Abdulaziz City for Science and Technology (Saudi Arabia)
LAGEOS	LAser GEOdynamics Satellite
LAN	Local Area Network
LAREG	Laboratoire de Recherches en G od sie (France)
LEO	Low Earth Orbit
LIDAR	Light Detection and Ranging
LLR	Lunar Laser Ranging
LOD	Length Of Day
LOSSAM	LAGEOS Spin Axis Model (The Netherlands)
LRA	Laser Retroreflector Array
LRE	Laser Retroreflector Experiment
LRR	Laser RetroReflector
L+T	Swiss Federal Office of Topography
LURE	LUnar Ranging Experiment
MAO	Main Astronomical Observatory (Ukraine)
MCC	Mission Control Center (Russia)
MCC-M	Mission Control Center-Moscow (Russia)
MCEP	Mean Celestial Ephemeris Pole
MCP	Micro Channel Plate
MEDLAS	Mediterranean Laser Campaign
MEO	Medium Earth Orbit
MERIT	Monitoring of Earth Rotation and Intercomparison of Techniques
MIT	Massachusetts Institute of Technology (USA)
MLRO	Matera Laser Ranging Observatory (Italy)
MLRS	McDonald Laser Ranging System (USA)
MOBLAS	MOBile LASer Ranging System
MOM	Mobile Optical Mount
MOTIC	Modular Time-Interval Counter
MTLRS	Modular Transportable Laser Ranging System
MWG	Missions Working Group
NAPEOS	Navigation Package for Earth Observation Satellites
NASA	National Aeronautics and Space Administration (USA)
NASDA	National Space Development Agency (Japan)

NCL	University of Newcastle Upon Tyne (United Kingdom)
NCST	Naval Center for Space Technology (NCST)
NERC	Natural Environment Research Council (United Kingdom)
NEWG	Networks and Engineering Working Group
Nd: YAG	Neodymium Yttrium Aluminum Garnet
NIMA	National Imagery and Mapping Agency (USA)
NMD	National Mapping Division (Australia)
NMF	Niell Mapping Function
NNG	Near Earth Navigation and Geodesy
NOAA	National Oceanic and Atmospheric Administration (USA)
NP	Normal Point
NRIAG	National Research Institute of Astronomy and Geophysics (Egypt)
NRL	Naval Research Laboratory (USA)
NW&E	Networks and Engineering Working Group
OCA	Observatoire de la C te d'Azur (France)
OD	Orbit Determination
OPR	Optical Plot Reading
OS	Operating System
PAS	Polish Academy of Sciences
PC	Personal Computer
PCGIAP	Permanent Committee for GIS Infrastructure for Asia and the Pacific
PDF	Portable Document Format
PM	Polar Motion
PMT	Photo Multiplier Tube
PM/UT	Polar Motion/Universal Time
POD	Precise Orbit Determination
POLAC	Paris Observatory Lunar Analysis Center (France)
PPET	Portable Pico-Second Event Timer
PPN	Parameterized Post Newtonian
PRARE	Precise Range and Range-rate Equipment
PRC	People s Republic of China
PRN	Pseudo Random Noise
QC	Quality Control
QL	Quick-Look
QLDAC	Quick-Look Data Analysis Center (The Netherlands)
QLNP	Quick-Look Normal Point
R&D	Research and Development
RAM	Random Access Memory
RGDR	Regional Gas Dose Ratio
RINEX	Receiver Independent Exchange Format
RISDE	Russian Scientific Research Institute for Space Device Engineering
RITSS	Raytheon Information Technology and Scientific Services (USA)
RMS	Root Mean Square
RRA	RetroReflector Array
RSA	Russian Space Agency
RSG	Refraction Study Group
SALRO	Saudi Arabian Laser Ranging Observatory (Saudi Arabia)
SAO	Smithsonian Astrophysical Observatory (USA)

SAR	Synthetic Aperture Radar
SC	Station Coordinates
SCAR	Scientific Committee on Antarctic Research
SCL	Scientific Committee on the Lithosphere
SENH	Solid Earth and Natural Hazards
SETIC	Selective Time-Interval Counter
SG	Study Group
SGAC	Space Geodesy Analysis Centre (Australia)
SINEX	Software Independent Exchange Format
SLR	Satellite Laser Ranging
SLRP	Satellite Laser Ranging Processor
SNR	Signal to Noise Ratio
SOD	Site Occupation Designator
SOPAC	Scripps Orbit and Permanent Array Center (USA)
SP	Signal Processing
SPAD	Single Photoelectron Avalanche Detector
SPIE	International Society for Optical Engineering
SPWG	Signal Processing Working Group
SRI	Space Research Institute (Russia)
SRIF	Square Root Information Array
SR	Stanford Research
SRS	Stanford Research Systems
SSC	Set of Station Coordinates
SSV	Set of Station Velocities
STARSHINE	Student Tracked Atmospheric Research Satellite for Heuristic International Networking Experiment
SUNSAT	Stellenbosch UNiversity SATellite (South Africa)
SV	Station Velocities
S/W	Software
SXO	Single Crossover
SYRTE	Syst me de Ref r nce Temps-Espace (France)
TAI	International Atomic Time
TB	TerraByte
TBF	Time Bias Function
TCP/IP	Transmission Control Protocol/INTERnet Protocol
TIGO	Transportable Integrated Geodetic Observatory
TIRV	Tuned Inter-Range Vector
TLRS	Transportable Laser Ranging System
TOPEX	Ocean TOPography Experiment
TP	Technical Publication
T/P	TOPEX/Poseidon
TRANET	TRAnsit NETwork
TRF	Terrestrial Reference Frame
TROS	TRansportable Observation Station
TROS	Transportable Range Observation System
TUM	Technical University of Munich (Germany)
UK	United Kingdom
UMBC	University of Maryland Baltimore County (USA)
UN	United Nations
UNEP	United Nations Environmental Programme
UNESCO	

UPF	Universit de la Polyn sie Fran aise (French Polynesia)
UPS	Uninterruptible Power Supply
URL	Uniform Resource Locator
US	United States
USA	United States of America
USNO	United States Naval Observatory
UT	Universal Time
UT	University of Texas (USA)
UTC	Universal Coordinated Time
UTOPIA	University of Texas Orbit Processor (USA)
UTX	University of Texas (USA)
UTXM	University of Texas McDonald Observatory Lunar Analysis Center (USA)
VCL	Vegetation Canopy LIDAR
VLBI	Very Long Baseline Interferometry
VNIIFTRI	All-Russian Scientific Research Institute for Physical-Technical and Radiotechnical Measurements (Russia)
VOL	Variation Of Latitude
WEGENER	Working Group of European Geoscientists for the Establishment of Networks for Earthquake Research
WESTPAC	Western Pacific Laser Tracking Network Satellite
WG	Working Group
WLRS	Wettzell Laser Ranging System (Germany)
WMO	World Meteorological Organization
WPLTN	Western Pacific Laser Tracking Network
WWW	World Wide Web
Y2K	Year 2000

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	June 2002	Technical Publication

4. TITLE AND SUBTITLE
International Laser Ranging Services (ILRS) 2001 Annual Report

5. FUNDING NUMBERS
Code 920.1

6. AUTHOR(S)
Edited by: Michael Pearlman, Mark Torrence, and Carey Noll

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS (ES)
Goddard Space Flight Center
Greenbelt, Maryland 20771

8. PEFORMING ORGANIZATION REPORT NUMBER
2003-00851-0

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS (ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
TP-2002-211610

11. SUPPLEMENTARY NOTES
M. Pearlman: Harvard-Smithsonian Center for Astrophysics

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Unclassified–Unlimited
Subject Category: 46
Report available from the NASA Center for AeroSpace Information,
7121 Standard Drive, Hanover, MD 21076-1320. (301) 621-0390.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This 2001 Annual Report of the International Laser Ranging Services (ILRS) is comprised of individual contributions from ILRS components within the international geodetic community.

This report documents the work of the ILRS components for the year 2001. The report documents changes and progress of the ILRS. This document is also available on the ILRS Web site at http://ilrs.gsfc.nasa.gov/reports/ilrs_reports/ilrsar_2001.html.

14. SUBJECT TERMS
Laser Ranging, Space Geodesy, Geophysics, Geodynamics, ILRS

15. NUMBER OF PAGES
176

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL