DEVELOPMENT AND IMPLEMENTATION OF JOINT PROGRAMS IN LASER RANGING AND OTHER SPACE GEODETIC TECHNIQUES

Contract NAS5-01113

Annual Report 3

For the Period: 1 April 2003 through 31 March 2004

Principal Investigator
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ANNUAL REPORT

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International Programs

WEGENER

During this reporting period as the NASA Special Consultant to WEGENER, Dr Pearlman continued to provide program coordination between NASA and the WEGENER Consortium. Pearlman provided technical, organizational, and functional support to the WEGENER Program and worked to facilitate group interaction among the WEGENER participants.

WEGENER will continue to provide a forum for European Scientists and serve as an umbrella for geodynamics activities in the region. Pearlman will participate in the WEGENER Board meeting in Nice at EGU. It is very unlikely that he will be able to attend the WEGENER Plenary Meeting in Tangiers, Morocco on 21 - 23 September 2004 due to funding limitations. Hopefully Rob Reilinger from MIT will attend.

Arabian Peninsula Programs

The SLR operation in Riyadh continues at an impressive level under the direction of John Gilfoyle. The station tracked nearly 6000 passes last year with sub-cm precision, making it one of the top-performing systems in the network. Data typically arrives at the CDDIS within a few hours of acquisition and is routinely used by the international scientific community.

With NASA and NSF funding, four GPS receivers have been placed in Saudi Arabia as part of a joint Saudi-US program through MIT to measure the dynamics of the Arabian Peninsula. The US provided the equipment and the Saudis provided most of the infrastructure. (These four stations will be used in conjunction with other GPS stations to be located in country by the Saudis.) Under this program, two of the US furnished GPS receivers have been operational for about a year: one on the north coast of the Red Sea (just below the Jordanian border) and one on the south coast of the Red Sea just north of the border with Yemen. These receivers are taking data. The other two US furnished receivers were placed in Riyadh (at the SALRO site) and at Jeddah (along the central Red Sea coastline).

Representatives from SALRO have participated in the bi-annual International Workshops on Laser Ranging and in meetings of the ILRS. A small SLR workshop was planned for Riyadh in late September 2001. The 9/11 events put this on hold along with several other events at the time.

Asia-Pacific Space Geodynamics (APSG) Program

The proceedings of the APSG meeting in Irkutsk in August 2002 have been issued. The next APSG meeting will be held in Singapore in early July 2004. Pearlman is not planning to attend due to funding limitations.

International Laser Ranging Service (ILRS)

International Workshop on Laser Ranging

Thirteenth Workshop

The proceedings of the Thirteenth International Workshop on Laser Ranging have been distributed. They can be viewed at http://cddisa.gsfc.nasa.gov/lw13/lw_proceedings.html. The full proceeding will be issued on CD. The Science section will be issued in hard copy.

Fourteenth Workshop

Pearlman and Carey Noll are working with the Real Instituto y Observatorio de la Armada on the planning for the Fourteenth International Workshop on Laser Ranging in San Fernando, Spain, June 7 - 11, 2004. The Program Committee met in Koetzting during the Laser Workshop to formulate the initial program. The website has been established at:

http://roasf2.roa.es/14workshop-laser/

The agenda for the Workshop appears in Attachment 1.

ILRS Meetings in Nice, France in April 2003

Pearlman organized and participated in the ILRS General Assembly and Central Bureau meetings in Nice, France in conjunction with EGU 2003. He also participated in the Working Group meetings and helped to prepare meeting notes. The list of action items from the Nice Governing Board meeting is included in Attachment 2. Pearlman has been working with the ILRS Central Bureau and the service members to address these items. In Nice, Pearlman also participated in the CSTG Board meeting, giving the ILRS Report and the report on the Ground Survey Working Group.

SLR Workshop in Koetzting, Germany, October 27 - 31, 2004

Pearlman worked with Ulli Schreiber to organize the SLR Workshop in Koetzting, Germany. Pearlman organized the sessions and the session's chairs. Pearlman ran some of the sessions and worked with Carey Noll to organize the writing and assembly of the meeting report. The Issues and Action Items from the meeting are included as Attachment 3.

Topics discussed in the sessions included improved data throughput, daylight ranging, comprehensive on-line engineering files, inter-technique ground survey techniques, improved quality control at both the Data centers and at the stations, the implementation of dynamic priorities, improved system calibration, better refraction models, rapid data throughput on LEO satellites, improved spacecraft center-of-mass corrections and documentation, two wavelength ranging, and the emerging role of automation to SLR

We also had the opportunity to review the Analysis Working Group progress in its Pilot Projects and their advancement toward unified ILRS data products, new approaches in analysis techniques, kilohertz ranging including the SLR2000.

Working Groups

The Analysis Working Group continues to work on its Pilot Projects as it progresses toward the formation of standard solutions for use by the IERS and other users. The Analysis Working Group is planning to meet just prior to the EGS meeting in Nice in April and San Fernando Workshop in June. The Missions Working Group has been working with the Central Bureau on schemes for Dynamic Priorities. The Networks and Engineering Working Group has undertaken the formation of a comprehensive engineering database for improved systems diagnosis and control. The Signal Processing Working Group has been working with the Central Bureau on a comprehensive web based file of satellite center-of-mass corrections. The Data Formats and Procedures Working Group is working on a new extended data format and improved refraction corrections. A Lunar Ranging Working Group is being planned.

Central Bureau

Central Bureau meetings have been held monthly during this reporting period. With the tremendous help from Van Husson, Carey Noll, and Scott Wetzel, Pearlman continued to oversee the daily activities of the service. The 2002 ILRS Annual Report has been finalized and is ready for distribution.

Van Husson issued the Fourth Quarter 2003 Stations Report Card in October. Work continued on refinements of the Site Log file on the web site and on the "range bias file". Hoai Vo, Van Husson, and Carey Noll did considerable work on the ILRS website. In particular the Station Information Section was greatly enhanced with comprehensive performance assessment information.

Central Bureau and NASA's participation in the ILRS has been severely impacted by the program reductions that were implemented in December. Many of the key Central Bureau and support people including Van Husson, Julie Horvath, Scott Wetzel, Jim Long and Hoai Vo are no longer associated with the SLR program. Many of the Central Bureau functions can no longer be fully accommodated.

Predictions

Sub-daily predictions continue to help tracking on low satellite. HTSI and CSR have a new prediction process that includes GPS data in the prediction cycle for GRACE and ICESAT. We need to invoke this process for the GPS satellites. The EUROLAS on-line prediction update and station status reporting has improved tracking. The NASA stations are now using it. We are encouraging all of the stations to try it.

Stations Qualification

We began reporting network status under the new Station Qualification protocol. The GPS requirement for Operational Stations status will be delayed until July 1, 2004 to allow a few stations to complete their purchase and installation.

Site Surveys

The Collocation/Survey meeting sponsored by the IERS was held in Matera, Italy on October 23 and 24. Pearlman worked with Chopo Ma, Zuheir Altimimi, Jim Long, and Bernd Richter to organize the sessions and recruit speakers. At the last minute Pearlman's travel plans were cancelled do to programmatic issues at NASA. The important recommendations from the meeting included:

- Local ties between co-located instruments should be determined with an accuracy of 1 mm, with full variance/covariance information, available in SINEX format.
- Local survey measurements should have the same importance as and should be treated like any of the space geodetic techniques. Site coordinates (VLBI, GPS, SLR, DORIS) should be better tied to the ground. The local ties quality should be such that they can be assumed true for the combination.
- All GPS sites close to other geodetic techniques should be part of the IGS routine processing.
- A database will be established at IERS (Central Bureau and ITRS Product Center) for all information in connection with site co-location (list of co-location sites, local ties in SINEX, co-location instruments, site maps and pictures, survey reports, survey status, site events and history ...).

An IGN/Shanghai Observatory team completed the site survey at Shanghai. A number of site survey analyses have yet to be completed by Jim Long. GSFC is trying to make arrangements with HTSI to complete this work on a timely basis.

Satellite Center-of-Mass Corrections

Dave Arnold completed his 6-month contract to help with the satellite center-of-mass and other engineering calculations. Some of his latest calculations are being included in the Koetzting report.

AMOS Meeting

Pearlman gave a presentation on the ILRS at the Special SLR Session at the Air Force AMOS meeting in Maui, Hawaii in September 8 -13, 2003. A copy of the paper is included as Appendix 4.

Support for the NASA Network

Data Engineering

The SLR Data Engineering Panel met regularly during this period, focussing most of its efforts on the activities of the ILRS, but some time was spent on performance assessment of the stations.

SLR Operations

Pearlman continued to provide technical and operational support and overview for NASA in the field of laser ranging, including system performance evaluation, system diagnosis, and system engineering, and provided technical support to the HTSI engineering and software staff.

SLR 2000

Pearlman provided some support to the SLR2000 to help in its presentation to management and in its project planning.

NASA Program

Pearlman worked with the project office to help accommodate a drastic funding reduction in FY2004. Pearlman, Chopo Ma, and Frank Webb gave the Space Geodesy presentation at the SENH Focus Area Review at NASA HQ on the April 25. He also orchestrated a letter writing campaign to NASA Headquarters and GSFC in attempt to educate management on the importance of the SLR and NASA's role in the SLR

international activity. Pearlman continues to work with GSFC to try to ease the transition and maximize the output at the significantly reduced level of funding.

INDIGO

The joint JPL/NASA proposal to the NASA Cooperative Agreement (CAN) has been funded at the level of $500K for 4 years. This project is intended to fund the development of an intelligent information system that will integrate the three geodetic services (ILRS, IVS, and IGS) and possible other services over time. Task planning, scheduling, and costing is now underway. A small amount of INDIGO funding is programmed for Dr. Pearlman.

Attachment 1

14th International Workshop on Laser Ranging
San Fernando, Spain
June 7 - 11, 2004

Agenda

Saturday, June 5

9:00 - 17:00 ILRS Analysis Working Group Meeting (R. Noomen, P. Shelus)

Sunday, June 6

9:00 - 1700 Registration
ILRS Working Group Meetings (to be scheduled at 9:00, 11:00, 13:00, and 15:00)
Missions, Data Formats and Procedures, Networks and Engineering, and Signal Processing

18:00 - 20:00 Reception (could be Sunday or Monday evening)

Monday, June 7

8:00 - On-Site Registration

9:00 - 10:00 Welcome

10:00 - 10:30 Break

10:30 - 12:30 Scientific Achievements, Applications, and Future Requirements I
(B. Schutz and J Garate)

12:30 - 14:00 Lunch

14:00 - 15:30 Scientific Achievements, Applications, and Future Requirements II
(R. Biancale and H. Drewes)

15:30 - 16:00 Break

16:00 - 17:30 New Applications
(J. Degnan and J.-M. Davila)

Tuesday, June 8

9:00 - 10:30 Laser Technology (G. Bianco and Y. Fumin)

10:30 - 11:00 Break

11:00 - 12:30 Improved and Upgraded Systems (Poster Briefs and Poster Session)
(L. Combrinck and S. Schillak)

12:30 - 14:00 Lunch

14:00 - 15:30 Ranging Receivers (I Prochazka and B. Greene)

15:30 - 16:00 Break

16:00 - 17:30 Automation and Control Systems (J. McGarry and W. Gurtner)

18:00 - 23:00 Trip to the Observatory, Reception

Wednesday, June 9

9:00 - 10: 00 Lunar Laser Ranging (P. Shelus and J.-F. Mangin)

10:00 - 10:30 Break

10:30 - 12:30 Engineering and Q/C Analysis (R. Noomen and V. Glotov)

12:30 - 14:00 Lunch

14:00 - 15:30 System Calibration Techniques (U. Schreiber and F. Koidl)

15:30 - 16:00 Break

16:00 - 18:00 ILRS Governing Board Meeting

Thursday, June 10

9:00 - 10:30 Targets, Signatures and Biases (G. Appleby and T. Otsubo)

10:30 - 11:00 Break

11:00 - 12:30 Atmospheric Correction and Multiwavelength Ranging (C. Luceri and S. Riepl)

12:30 - 14:00 Lunch

14:00 - 15:30 Advanced Systems and Techniques (F. Pierron and H. Kunimori)

15:30 - 16:00 Break

16:00 - 18:00 Operational Issues (M. Pearlman and G. Kirchner)

20:00 - 23:00 Banquet (is this the correct time?)

Friday, June 11

9:00 - 10:30 ILRS General Assembly

10:30 - 12:30 Workshop Summary, Resolutions, Closure

Paper titles and abstracts are requested by May 1. Please try to get them in earlier if possible. We would like to distribute them electronically prior to the meeting.

Registration is requested by May 1 so that facility arrangements can be finalized.

Papers may be specified as oral or poster. Poster presenters will be given 5 minutes to give oral summaries of their presentations.

Papers in the Improved and Upgraded Systems Session will be given as posters with oral summaries. Some papers in other sessions may also be deferred to posters with oral summaries. The Organizing Committee reserves the option of moving papers to the Poster Sessions if necessary for time or program considerations.

Attachment 2

ILRS Governing Board Report
Nice, France
April 9, 2003

Attendees and Agenda:

Ron Noomen, Graham Appleby, Wolfgang Seemueller, David Carter, Pippo Bianco, Peter Shelus, Georg Kirchner, Werner Gurtner, Hermann Drewes, Bob Schutz, and Mike Pearlman

The meeting agenda and the agenda for the General Assembly are included in Attachments 1 and 2.

Review of Tracking Status

Mission Items

Tracking is proceeding well on the new active satellites, GRACE A/B, Jason, and ENVISAT.

The Reflector tracking campaign ended in February 2003. The IPIE is very pleased with the 3,670 passes acquired from December 2001 through March 2003. Analysis of the data is underway. A limited ADEOS-2 tracking campaign was conducted from December 2002 through January 2003 to help define the orbit. A few pre-approved stations are continuing the tracking support, as great care is being taken not to jeopardize the on-board optical sensors. Etalon tracking was officially changed from campaign to "regular" status in October 2002 to support Earth rotation measurements, gravity field modeling, and station quality control. ICESat was launched on January 12, 2003. A few carefully selected SLR stations started tracking in March 2003, as the tracking operations plan is being developed to avoid risk to the on-board optical detectors. HTSI is generating predictions based on both GPS and SLR. STARSHINE-3 re-entered on January 21, 2003. Although not an official ILRS missions, it was being tracked by some of the stations.

Gravity Probe B is scheduled for launch in November.

Station Items

The Maui SLR has finally emerged from upgrading with much improved performance. The now operational MLRO is providing SLR and LLR data. The Mount Stromlo station was destroyed by fire in January 2003; station will be rebuilt. The refurbished CRL station at Koganei, Japan is now back in operation. The National Astronomical Observatory, Academia Sinica mobile system is currently undergoing system testing in Beijing in preparation for relocation to the San Juan Technical University in Argentina later this year.

The FTLRS completed an occupation in Ajaccio, Corsica in September 2002 and is now being relocated to Chania, Crete. The TIGO is operational at Concepción Chile. The new SLR stations in Potsdam, Germany and Lviv Ukraine are now operational. Work proceeds on the SLR2000 and the new Lunar Ranging station at Apache Point in Washington State.

Local Survey

Site surveys have been a major problem impacting the space geodetic reference frame, especially related to

collocation of techniques needed for TRF combination. Problems include inconsistencies in the ground survey techniques used, the survey network geometries, the survey analysis, the documentation, discrepancies between site survey and TRF results, etc. The ISGN committee under John Bosworth made an assessment of the local survey status for each station in the SLR and VLBI networks; an action plan with priorities was developed.

A Joint Service team with IGN (Zuheir Altimimi), IVS (Chopo Ma), ILRS (Mike Pearlman), and NASA/Survey Team (Jim Long) are building on the earlier activity. This team will probably evolve into a working group within the new IAG organization, perhaps under the IERS. Jim Long has developed and circulated draft survey standards documents and he is running tutorial survey sessions at major meetings. A joint IGN/NASA team was making arrangements visit Shanghai to participate in a site survey and to compare survey techniques with the Chinese survey team (the SARS epidemic has delayed this). Discussions are underway with HartRAO on a planned site survey

The Survey Team plans to hold a survey workshop for practitioners on Thursday and Friday, October 23 and 24. The workshop will focus on survey techniques, analysis, data bases, and plans for resolving the local survey shortfalls that currently exist with the SLR and VLBI networks.

Additional people with survey experience are needed on the team to help educate others and to participate in the site surveys at critical stations.

There is concern that some stations may not have ground markers for their local survey tie. These shoul dbe strongly recommended.

Operational Issues

Full rate date is now flowing routinely into the Data Centers. The ILRS web site has been updated with a new navigation scheme, a new front-page bulletin board, and additional station performance, diagnostic, and operational practices web pages. Web site acquisition statistics are now available at

http://ilrs.gsfc.nasa.gov/awstats

Working Group Highlights

Analysis Working Group

Work proceeds on the Pilot Projects. The Benchmarking and Orbits Project is comparing parameter solutions to isolate "blunders" and software inconsistencies. The Harmonization Project continues the development toward a unified means of identifying system biases. The Positioning and Earth orientation Project continues our development toward unified, official ILRS combination position and EOP products
A Call for Participation under the Positioning and Earth orientation activity was issued in November. Groups responded for both individual SLR solutions and combination products.

The Analysis Working Group met on March 31 - April 1 to review progress and plans paced toward an evaluation of results at the next Working Group Meeting on October 26 - 27. Key dates are submission of benchmark solutions by May 31, submission of analysis solutions by October 1, and evaluation of combination solutions by October 21.

The IERS plans to move to more stringent data products. They want to move to rigorous combination solutions of networks on a weekly basis and EOP on a daily basis. The ILRS is expected to participate with a single or a combination product, which should be available with no more than a 4 - 6 weeks delay. The IERS is planning to undertake a Pilot Project to test this concept. A Combination Working Group will be established on May 1, 2003, a Call for Proposals to do the technique solution combinations will be issued at the end of June, proposals are due on September 15, proposals will be evaluated by early October, and the pilot project will start on January 1, 2004. It is anticipated that this new combination product will replace the current product and that the old SLR, VLBI, and GPS data will be reprocessed in this manner. A time-series of weekly solutions should eventually evolve into multi-year solutions. With this in mind, The Analysis Working Group is updating its solutions to be compatible with this new one week/one date requirement.

A revised plan for station qualification was presented and discussed. With a few modifications, it was recommended that the plan be brought before the Governing Board for approval. (See Station Qualification below).

The Analysis Working Group plans to hold its next meeting at Wettzell, on Sunday and Monday, October 27 and 28, just prior to the ILRS fall meeting.

Networks and Engineering Working Group

The response to the Minimum Number of Returns per Normal Point Criteria that was approved by the Governing Board last year was reviewed. (See Minimum Normal Point Criteria below.)

Some stations are benefiting from the Global Use of Real-Time Time Bias Exchange and Time Bias Prediction File. Another notice will be sent out to encourage implementation

Work is underway by Van Husson on "MyStationPerformance.Com" a means for the stations get an assessment of their performance. Van is also working on new powerful bias-detection capabilities using a combination of data analysis and ancillary data tools.

As we approach mm range performance, on-station engineering data checks and tests are even more essential to reveal, understand, and correct system biases. It is unrealistic to rely on the after-the-fact analysis. The working group is initiating a comprehensive Engineering Data File (EDF) that should be maintained at each station, which can be queried in intelligent ways to expose problems. The file would contain station parameters, settings, calibration and ranging information, meteorological data, etc. The working group is developing a flexible format to allow stations to begin by participating at their own level. With the file, each station should be able to check for consistency, linearity, jumps etc., and the analysis groups could easily cross-correlate residual signatures.
Several stations (Matera, RGO, Graz, NASA) have agreed to check the possibilities using their systems, and to implement the data file as soon as a first test format is defined. First results will be reviewed at the Koetzting meeting in October.

Data Formats and Procedures

Prediction Format Study Group

The latest version of the new proposed extended format includes some updates in response to the most recent suggestions. Werner Gurtner has been investigating the accuracy of normal points using the new format and a

sample integrator, used LaGrange polynomials of order 6 with the time of interpolation always being in the central interval of the polynomial. On LAGEOS, Starlette and Stella (1) the interpolation in geocentric space (x, y, z) produces orders of magnitude better results than interpolating in topocentric space (az, el, range), and the (2) the interpolation of predictions over a pass gives deviations from the reference orbit of about 1 mm for LAGEOS and worse for other satellites. However, breaking the pass into segments the length of a normal point and fitting these segments gives much smaller deviations. Further improvement can be achieved with a higher order of the interpolation.

Work continues on the format with SLR, LLR, and Mars spacecraft predictions. The next steps for this study group are to revise the formats, work on sample code, document the algorithms, and start field tests.

Refraction Study Group

Several reports were given on refraction. Attempts to update the Marini and Murray model offer some promise, especially at low elevations. Early two wavelength data from Matera looks interesting. Analyses of residual patterns at low elevations also look interesting. There was a general request for the stations to take more low elevation data, down to 0 degrees if possible, on a selected set of satellites to provide a more robust data set for investigation. The CB will query the stations on their constraints to tracking below 20 degrees altitude and request that they lower their tracking horizons as low as possible on selected satellites

Missions Working Group

The Missions Study Group focussed mainly in the issue of Dynamic Priorities. Bart Clark reported on a comprehensive scheduler that is being developed by Honeywell. The system will have sufficient flexibility to interleave passes, adjust priorities by satellite and by station, and make use of historic information and decision algorithms formulated by the ILRS or by subnetworks. Honeywell will implement and manage the program and the service for any stations that are interested. The software is an outgrowth of the schedulers now used by the NASA network and will evolve in steps that are digestible for the field stations.

Mike Pearlman presented some thoughts on less ambitious concepts that had been discussed by several Governing Board members. See Dynamic Priorities below.

Signal Processing Working Group

Center-of-mass corrections (CoM) for the principal spherical geodetic satellites LAGEOS, ETALON and AJISAI for the three main tracking system types, single-photon, C-SPAD and PMT/MCP have been tabulated. The corrections have been evaluated as functions both of numbers of photoelectrons and of data clipping procedures for the single-photon detectors and as functions of pulse width for the 'leading edge' (PMT/MCP) systems.

In order to take best advantage of this information, some measure of estimated return level should be available in the ILRS normal point data taken by all the tracking systems. This information would supplement the general information on detector characteristics that is available in the site log file. The information would probably only need to be fairly 'course' and averaged over each normal point bin.

The Working group will examine whether there is currently enough information in the site logs to properly characterize each station, pursue whatever is missing, and recommend a means of coding signal strength in a rough categories in the normal point file.

The Working Group has also been requested to compute CoM values for STARLETTE and STELLA.

Work is underway on the development of a web page that tabulates all of the CoM information for the users. A format has been proposed by Mark Torrence and links to CoM correction tables, taken from Otsubo & Appleby, 2003, are in place for the spherical satellites. Some details have also been tabulated on satellite-fixed coordinates for LRA phase centers on other satellites. See

http://ilrs.gsfc.nasa.gov/satellite_missions/center_of_mass/

Lunar Working Group (Tentative)

The Lunar Ranging Community is preparing a charter for presentation to the GB for the formation of a Standing Working Group.

ILRS Station Qualification

Previous plans for formal qualification of ILRS stations had met resistance from some members of the Governing. Board. Some did not support designation into three categories (Core, Operational, and Associate stations), and some were sensitive to the precipitous "demotion" of weak stations for fear the they would loose local support. There was also the issue of whether special mobile" stations could qualify on LEO satellites only.

Mike Pearlman presented a revised plan that had been worked up by several members of the Governing and revised by the Analysis Working Group.

All ILRS Stations would be classified as Operational or Associate, with all current stations initially considered as Operational. New stations accepted as Associate by the Central Bureau upon submission of ILRS Station Response form. Associate stations would become Operational by:

1. submitting a valid site log,
2. delivering at least 10 passes of normal point data to the CB which then pass CB format and data integrity validation,
3. delivering at least 20 LAGEOS passes over a consecutive 3-month period to an ILRS operations center,
4. passing a data evaluation by Analysis Working Group (see below),
5. being approved by Governing Board

The data evaluation criteria would be:

1. normal point RMS of 1 cm (Shanghai Criteria)
2. short term range bias stability of 4 cm (twice Shanghai Criteria)
3. normal point acceptance rate of 80%

As of January 1, 2004 all ILRS stations would be evaluated on a quarterly basis. To be classified as Operational, a station must have submitted (1) at least 50 valid LAGEOS passes (as described above) in any 3-month period during the previous 12 months; and (2) a current site log. Those stations that do not satisfy these requirements will be relegated to "Associate" status. Station status, Operational or Associate, would be denoted on Quarterly Report Cards issued by the CB. Stations must range to LAGEOS to be categorized as

Operational.

It was also agreed that Operational stations must have collocated GPS receivers in routine operation.

The Analysis Working Group is welcome to designate a network of higher performing core stations for its users and may list this on their web site.

The Governing Board approved this proposal. The CB will send out a notification on Station Qualification and will augment the current Report Card program to denote categories by January 1, 2004.

Assessment of On-line Prediction Updates

Werner Gurtner reported that Graz, Wettzell, Potsdam, Zimmerwald, Grasse, and Herstmonceux are presently feeding the on-line tracking exchange. Thirteen stations are accessing the website, presumably for rapid prediction updates. All stations are encouraged to use the service and to give feedback on how the service may be more helpful.

Dynamic Priorities

Mike Pearlman presented some concepts on dynamic priorities that had been under discussion.

We have two cases to consider:

1. Data is very abundant or very sparse and we want to key stations to adjust their tracking priorities; and
2. We want to decrease (or increase) tracking overlap between stations that are in close spatial proximity.

Case 1

In the first case we have mid-altitude satellites such as Be-C and Ajisai that are being overly tracked, while data should be increased on Etalon, GLONASS, and GPS. Two approaches are being considered:

1. The CB would monitor data yield and issue a priority update key on the AIUB real-time prediction service for each satellite based on a GB approved criteria. The key would be based on recent tracking density and elapsed time since the last pass was acquired. The index might run from +2 (top priority) to -2 (do not track at all). Numbers would be adjusted as we gain experience.
2. Stations would be issued the minimum number of passes that we expect per satellite per day or week. When those minimum numbers are achieved, stations should then focus on conflicting lower priority satellites whose minimum has not yet been achieved

The Analysis Working Group preferred the second option.

Case 2

The station overlap condition is mainly in Europe. Some stations in Europe are already registering their real-time status on-line using the AIUB real-time prediction service. One station can see if another is already tracking a particular satellite and then make a decision based on data criteria. The remaining stations in Europe should be encouraged to join in this process and decision-making criteria need to be established. Whether data overlap should be increased or decreased depends on how much overlap is required for data quality control.

The Central Bureau will make a proposal on case 1. A solution for case 2 should probably be proposed by EUROLAS.

Minimum Normal Point Criteria

Many stations are not adhering to the Minimum Number of Returns per Normal Point Criteria approved by the Governing Board. This is an important means of self-examination by the stations and a way to improve the data for our users. The Central Bureau will notify the delinquent stations and prepare a status review for the fall meeting.

Spacecraft Center of Mass

Topic covered under Signal Processing Working Group Report above.

Fall Meeting

The SPIE will not be able to accommodate our ILRS meetings in Barcelona as originally planned due to space limitations. Two alternative proposals have been graciously offered - Wettzell (BKG) and Canberra (AUSLIG). Because of logistics, and the need to arrange a tandem meeting on Local Surveys, the GB preferred that the meeting be held at Wettzell.

The meetings would be held Tuesday through Friday, October 28 - 31. The plan is to have specialized sessions to address specific topics and either bring them to closure or get them properly formulated so they can be properly acted upon. Each Working Group and or Study Group will be responsible for organizing at

least one topic session. Additional topic sessions may also be organized. Topic examples include refraction model, prediction format, spacecraft center-of-mass correction, dynamic priorities, local survey issues, hardware characterization, data flow, etc.

Sessions would be scheduled in tandem so everyone could participate. No formal General Assembly would be scheduled, but a general meeting and a Governing Board Meeting would be organized to allow some discussion
The CB will work with the local meeting organizers and the Working Groups to get the meetings organized.

The Analysis Working Group will schedule a 2-day meeting at Wettzell, just prior to the fall meeting, probably on Sunday and Monday, October 26 and 27. The Survey Group plans to schedule a Working Group Meeting just prior to the Analysis Working Group Meeting. The Survey Group Meeting will probably be held at Matera on
Thursday and Friday, October 23 and 24.

ILRS Annual Report

The Annual Report 2001 is available on the web and in hard copy. The call is out for contributions for the Annual Report 2002. This report, which will be structured around issues and topics rather than ILRS entities, should be considerably shorter that the previous reports. The Table of Contents for AR2002 is included as Attachment 1. Assignments have been made and contributions are due to Carey Noll by May 9.

International Workshop on Laser Ranging

All session summaries from the Thirteenth International Workshop on Laser Ranging held in Washington D.C. are posted on the workshop web site along with the workshop summaries and the resolutions. See

http://cddisa.gsfc.nasa.gov/lw13

So far, 66 presentations, 11 posters, and 87 papers are posted on the web site out of a total of 113 papers. The Proceedings will be issued as a CD with hard copy of the science and applications papers. A concerted effort is presently being made to encourage the last few submissions. In particular, we want to include as many of the science papers as possible.

The Fourteenth Workshop will be held in San Fernando in June 2004. Each of the Networks has been requested to name a person for the Organizing Committee.

Action Items

1. All Operational stations should have GPS receivers and be IGS Global Station, following IGS Standards with continuous data delivery (CB will check TOR and submit for GB approval);
2. Secure IERS written support for SLR and LLR (Noomen and Shelus)
3. Check all old SLR stations (back through Merit) for Domes Numbers (CB);
4. Check availability and interpretability of early data at least as far back as Lageos I (CB);
5. Activate stations to track down to 0 degrees on Lageos, Jason, Envisat, CHAMP, and GRACE to support refraction studies (CB);
6. Develop proposal on Dynamic Priorities, considering suggestions from the AWG (CB);

7. Resolve data resupply and storage issue (Data Centers, CB);
8. Develop signal strength and detection reporting scheme by stations (SP W/G);
9. Contact delinquent stations on Minimum Normal Point data content issue (CB);
10. Query stations on available site engineering information (NE W/G);
11. Encourage stations to use real-time Prediction Update System (Gurtner/CB);
12. Expedite data flow from stations, through CB, to NERC for more rapid prediction updates; aim for 5 minute cycle intervals (DF&P W/G);
13. Set up Survey Working Group Meeting in Matera in October (CB, ISGN team and IERS);
14. Develop whole protocol and organization for the Survey Working Group (ISGN and IERS);
15. Include time bias for "yesterday's" prediction orbit on Real Time Prediction Update System (NERC);
16. Organize sessions for Wettzell meeting (Working Groups/CB);
17. Announce Station Qualification Policy as approved by the GB (CB);
18. Examine alternative analysis strategies for improving data products (Analysis Working Group, CB);
19. The stations should be queried if they have a ground marker for the station survey reference; if not, it should be strongly recommended (Survey Team and CB)

Attachment 3

Koetzting Workshop

Recommendations and Action Items

Daylight Ranging

- Stations must place greater stress on daylight ranging for provide better day-night data distribution.
- The CB and the Networks and Engineering Working Group will work with stations that can do daylight mount modeling to make information available about how this capability can be achieved.

Predictions

- HTSI should implement the repair to its IRV tuning process to correct the midnight offset problem.
- The CB will ask GFZ if they can speed up the prediction cycle for Champ and GRACE to improve data acquisition.
- The CB will remind ESOC of the offset issue and see if we can offer them any help.

Data Throughput

- The stations, data centers and the prediction centers must reduce the data - prediction update cycle time as much as possible.
- Stations should strive for data submissions after every pass, especially on the low, harder to track satellites such as CHAMP, GRACE, GFO-1, ERS-2, and Envisat
- Data Centers should strive for 10-minute turnaround times.

Dynamic Priorities

- CB will post the new dynamic priority table with daily updated indices on the AIUB server, so it will be available when stations access their prediction updates

On site Data Consistency Checks

- Stations must implement procedures for onsite monitoring of the consistency of their pass-by-pass calibrations, meteorology readings, and systems health-parameters. Time histories of key parameters should be used to reveal performance issues.
- RGO will upgrade its NP check program for easy implementation and make it available for other stations to use in local data screening
- Van Husson will also provide a set of tests for the stations to use to help identify data problems.

Minimum Data Criteria for Normal Points

- Stations may exercise their own discretion in setting minimum data criteria per normal point or disregard them all together. The GB recommends the 2002 criteria (6 data points per NP in daylight and 3 data points per NP at night) for single photoelectrons systems with high data yield. Stations with KHz return rates may select more stringent criteria. Stations must include their minimum NP data criteria as a note in their Site Logs

Signal Processing and Center-of-Mass Correction

- Stations should use signal return properties such as mean, peak-mean, skew and kurtosis to monitor systems performance. A team should be setup to definition the essential parameters and tests.
- Stations should quantify the range bias effect on specified satellites (e.g. LAGEOS, Ajisai and Envisat) over the pertinent dynamic range of their systems by switching range measurements between minimum and maximum return levels during ranging operations. The Signal Processing Working Group will specify a prescription for the stations to follow.

Two-Color Ranging

- The Signal Processing Working Group will investigate the dependence of retroreflector (internal) range correction on wavelength.
- The Data Formats and Procedures Working Group should address the misalignment of corresponding NP epochs between the two-wavelength data sets when using the standard NP construction procedure.
- The CB will devise a better way to report two-color simultaneous passes in the quarterly report card, rather than or in addition to the present method where the passes are reported separately.
- The CB, the Data Centers, and the Data Formats and Procedures WG will work with the two-wave length stations to implement a mechanism to deliver differential delay to the Data Centers.

Local Survey

- Stations should verify the survey of their system and target at least every two years. Current requirements are 1mm accuracy.
- Local ties between co-located instruments should be determined with an accuracy of 1 mm, with full variance/covariance information, available in SINEX format.

Refraction Model

- The Refraction Study Group and the Analysis Working Group will identify the steps necessary to implement the Ciddor-Mendes refraction model as the standard for the ILRS.
- Stations should strive to increase low-elevation (<20 degrees) tracking to support refraction model testing.
- The Refraction Study Group will draft a letter and suggest some laboratories that the CB might approach to provide the refraction constants.

Analysis and Data Products

- The AWG will investigate new analyses and data combination approaches to expand the SLR data product capability, in particular to further shorten product interval time.
- The AWG will assess the currently used IERS "background" models for tidally coherent signals in the geocenter and EOP and report back to the IERS Conventions Group.
- All analysis groups should have submitted their required benchmark solutions by the end of November 2003; the Benchmark 'judges' (Pavlis, *et al*) are tasked to report the Pilot Project results by the end of 2003.

- All analysis groups participating in the POS+EOP Pilot Projects should implement (1) 7-day data arc lengths and (2) epochs aligned to GPS week by mid-November 2003.
- The analysis coordinator will work with the IERS to determine how best to provide the SLR a weekly, timely ILRS EOP product for the IERS rapid service

General Calibration Recommendations for the stations from the workshops in Florence and Toulouse:

- Standardize the calibration procedure and minimize the manual system changes and re-adjustments
- Calibrate the SLR system at frequent intervals, providing pre and post calibrations for each satellite pass within a maximum time span of one hour.
- Keep a calibration history file of all relevant parameters for consistency verification.
- Collect a sufficient number of valid returns for all calibration sessions.
- Plot a histogram for each calibration session, compare with a Gaussian fit and check for anomalies in the distribution.
- Use optically correct calibration target(s).
- Use efficient spatial filtering.
- Use multiple targets at different azimuths and ranges to check the calibration setup and survey.
- Ensure a perfect alignment of the SPAD optics.
- Apply the gate for the detector early enough (50 ns and 100 ns for APD's) to avoid aliasing
- Keep an appropriate echo data rate < 15% for APD's < 80% for C-SPAD.
- Interpret properly the echo data rate.

The important recommendations from the Colocation Survey Workshop at Matera:

- Local survey measurements should have the same importance as and should be treated like any of the space geodetic techniques. Site coordinates (VLBI, GPS, SLR, DORIS) should be better (??) tied to the ground. The quality of local ties should be such that they can be assumed true for the combination.
- All GPS sites close to other geodetic techniques should be part of the IGS routine processing.
- A database will be established at IERS (Central Bureau and ITRS Product Centre) for all information in connection with site co-location (list of co-location sites, local ties in SINEX, co-located instruments, site maps and pictures, survey reports, survey status, site events and history, etc.).

THE INTERNATIONAL LASER RANGING SERVICE

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1. ABSTRACT

The International Laser Ranging Service (ILRS) was established in September 1998 as a service within the International Association of Geodesy (IAG). The Service supports programs in geodesy, geophysics, oceanography, and lunar research and provides the International Earth Rotation Service (IERS) with products important to the maintenance of an accurate International Terrestrial Reference Frame (ITRF). Now in operation for nearly four years, 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 laser ranging data to satisfy a variety of scientific, engineering, and operational needs and encourages the application of new technologies to enhance the quality, quantity, and cost effectiveness of its data products. The ILRS works with (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 ILRS Central Bureau maintains a comprehensive web site as the primary vehicle for the distribution of information within the ILRS community. The site, which can be accessed at: http://ilrs.gsfc.nasa.gov is also available at mirrored sites at the Communications Research Laboratory (CRL) in Tokyo and the European Data Center (EDC) in Munich.

The ILRS currently includes more than 40 SLR stations, routinely tracking more than 20 retroreflector-equipped satellites and the Moon in support of user needs. New missions added to the ILRS tracking roster over the past few years include CHAMP, GRACE A and B, Jason (in tandem with TOPEX), ENVISAT (in tandem with ERS-2), and Meteor-3M.

Through the continuous tracking of LAGEOS-1 and -2, the ILRS helps to maintain the Terrestrial Reference Frame (TRF) by providing time-varying geocenter coordinates and scale (GM). The terrestrial reference system is the basis through which we connect and compare measurements over space (1000 - 10,000 km) and time (decades). ILRS data are used to generate scientific and operational data products such as static and time-varying coefficients of the Earth's gravity field models, tides, Earth orientation parameters (polar motion and length of day), and three-dimensional station coordinates and velocities. The data are also used to determine precision satellite orbit ephemerides (for calibration and validation of satellite altimetry), fundamental physical constants, lunar ephemerides and librations, and lunar orientation parameters. SLR also provides tracking data for special engineering missions. Since several remote-sensing missions have suffered failures in their active tracking systems or have required in-flight recalibration. The ILRS continues to encourage 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.

2. ILRS ORGANIZATION

The ILRS is organized into the following components: Tracking Stations and Subnetworks, Operations Center, Global and Regional Data Centers, Analysis and Associate Analysis Centers, a Central Bureau, and a Governing Board (see Fig. 1).

ILRS Tracking Stations range to the approved constellation of artificial satellites and the Moon with state-of-the-art laser ranging systems and transmit data on an hourly basis to a specified ILRS Operations Center. Stations are typically associated with one of the three regional subnetworks: National Aeronautics and Space Administration (NASA), EUROpean LASer Network (EUROLAS), or the Western Pacific Laser Tracking Network (WPLTN).

ILRS Operations Centers collect and merge the data from the tracking sites, provide initial quality checks on these incoming data, reformat and compress the data if necessary, and relay the data to an ILRS Data Center. The Operation Centers are also tasked to maintain a local archive of the tracking data and to provide Tracking Stations with sustaining engineering, communications links, and other technical support.

ILRS Global Data Centers are the primary interface between the network of Tracking Stations and the Analysis Centers and general user community. The Data Centers receive and archive laser ranging data and supporting information from the Operations Centers, and provide these data on-line to the Analysis Centers. Furthermore, these centers receive and archive ILRS scientific data products from the Analysis Centers and provide these products on-line to users.

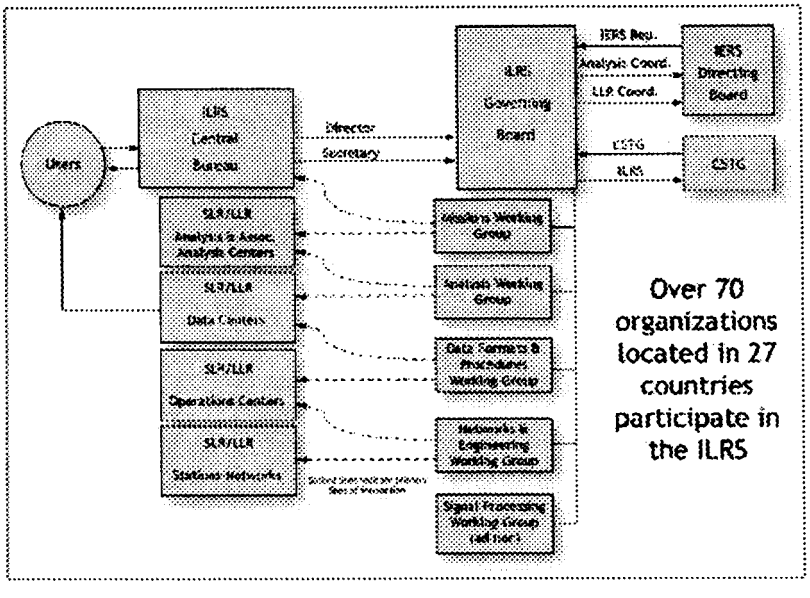

Fig. 1. Organization of the ILRS

The ILRS Analysis Centers (ACs) routinely process the global LAGEOS-1 and LAGEOS-2 data and provide Earth orientation parameters on a weekly or sub-weekly basis. The ACs also produce other products such as station coordinates and velocities and geocenter coordinates on a regular schedule and provide a second level of data quality assurance in the network. Specialized products, such as time-varying gravity field measurements, fundamental constants, satellite predictions, precision orbits for special-purpose satellites, regional geodetic measurements, and data products of a mission-specific nature are generated by Analysis and Associate Analysis Centers. Quality control functions are performed through the direct comparison of Analysis Center products. Lunar Analysis Centers produce LLR products such as lunar ephemerides, lunar libration, and Earth rotation (UT0 - UT1). All ACs deliver products to the Global Data Centers and the IERS using designated standards.

The ILRS Central Bureau (CB) is responsible for the daily coordination and management of ILRS activities. Central Bureau personnel facilitate communications and information transfer and promote compliance with ILRS network standards. The CB monitors network operations and quality assurance of the data, maintains all ILRS documentation and databases, and organizes meetings and workshops. Specialists within the ILRS enhance dialogue, promote SLR goals and capabilities, and educate and advise the ILRS entities on current and future science requirements related to SLR. Furthermore, the CB maintains the ILRS web site as the primary vehicle for the distribution of information within the ILRS community.

The ILRS Governing Board (GB) is responsible for the general direction of the service and defines official ILRS policy and products, determines satellite-tracking priorities, and develops standards and procedures. The sixteen-member body interacts with other services and organizations and is selected from ILRS associates representing all components of the service.

Within the ILRS Governing Board, Working Groups carry out policy formulation. Presently the ILRS has five working groups: Missions, Data Formats and Procedures, Networks and Engineering, Analysis, and Signal Processing. These working groups 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. The Working Groups were originally created to serve as the primary foci for Governing Board activities. All of the Working Groups have attracted talented people from the general ILRS membership who have contributed greatly to the success of these efforts.

3. TRACKING NETWORK

The ILRS network (see Fig. 2) is presently tracking over twenty retroreflector-equipped satellites and the Moon in support of user needs (some of these stations are in the process of development). Through international partnerships, the global distribution of SLR stations continues to improve, especially in the Southern Hemisphere, where coverage had been historically weak. The ILRS has also been giving strong encouragement to the development of Fundamental Reference Stations, where a combination several space geodetic techniques including SLR, Very Long Baseline Interferometry (VLBI), Global Positioning (GPS), DORIS, and absolute gravimetry are collocated to strengthen reference system constraints and system synergy. Most of the ILRS stations have a collocated GPS receiver that adheres to International GPS Service (IGS) standards As of mid-2004, this will be come a requirement.

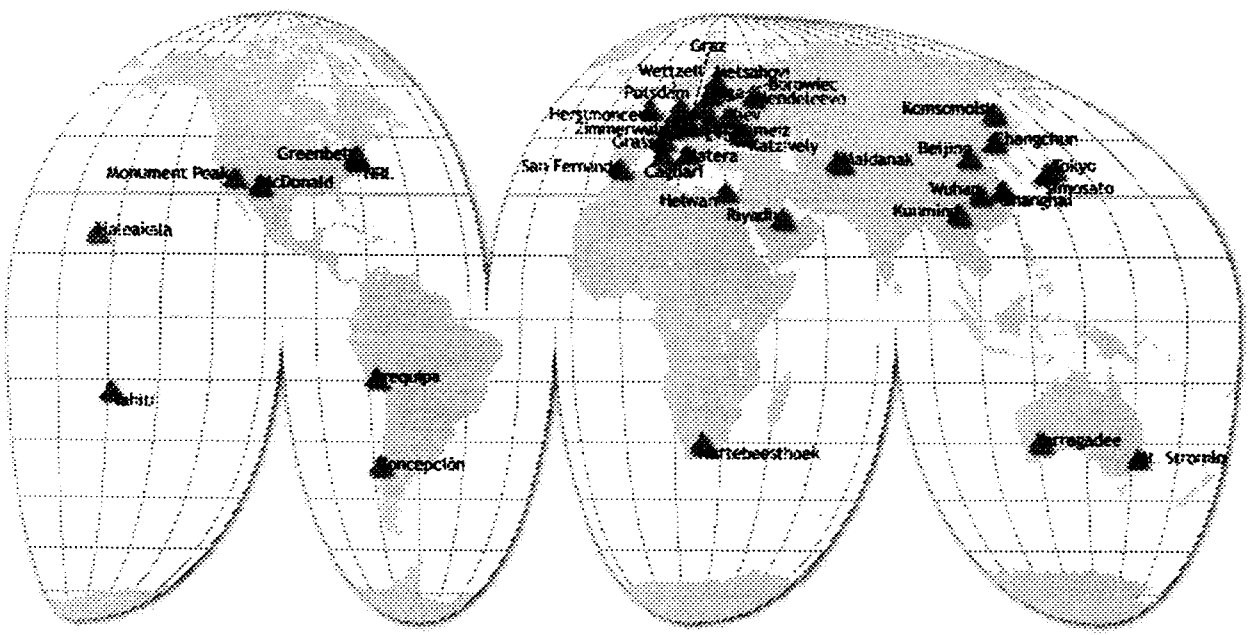

Fig. 2. ILRS Tracking Network (as of July 2003)

South America. The NASA Transportable Laser Ranging System (TLRS-3) system at the Universidad de San Agustin site in Arequipa, Peru, has been the major source of SLR tracking in South America for many years. In 2002, the Bundesamt für Kartographie und Geodäsie (BKG, Germany) and a consortium of Chilean Universities established a site at Concepción, Chile with the new BKG multi-technique Totally Integrated Geodetic Observatory (TIGO). The TIGO, with SLR, VLBI, GPS and absolute gravimetry, now provides the first multi-technique Fundamental Station in South America (Fig. 3a). Also strengthening the South American coverage will be a joint Chinese-Argentine SLR station planned for installation at the San Juan Observatory in western Argentina using a new system to be furnished by the Beijing Astronomical Observatory early next year.

North America. The performance of the Mt. Haleakala SLR system improved significantly in 2002 with the completion of the long awaited mount refurbishment. A new LLR station, being built by the University of Washington, will be located at Apache Point, New Mexico. Work continues on the prototype of the NASA totally automated laser ranging system (SLR2000); field-testing is planned for spring 2004 (Fig. 3b).

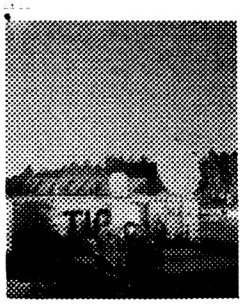

Fig. 3a. TIGO, Concepcion, Chile

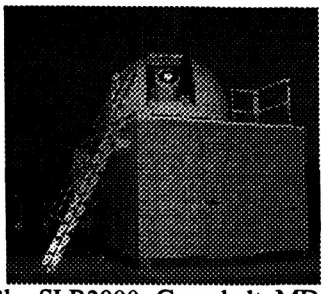

Fig. 3b. SLR2000, Greenbelt, MD, USA

Europe. The new state-of-the-art Matera Laser Ranging Observatory (MLRO) with both SLR and lunar ranging capability became operational in 2001 and is now operating with very impressive performance (Fig. 4a). Coupled with the on-site VLBI and GPS, Matera has now significantly improved its role as one of the European Fundamental Reference Stations. Several other European stations have also completed major upgrades or total system replacement. In 2002, the new SLR at the Astronomical Institute at the University of Berne (AIUB) in Zimmerwald, Switzerland (Fig. 4b) began two wavelength operations. This will be important to support atmospheric dispersion studies in addition to ranging. A new SLR station located at GeoForschungsZentrum Potsdam (GFZ) in Germany became operational in late 2002, also with considerably improved performance, replacing an older system that had been tracking for eleven years. The French Transportable Laser Ranging System (FTLRS, Fig. 4c) was operated in 2002 at the Ajaccio, Corsica in support of altimeter satellites, and is now operating in Chania, Crete.

Fig. 4a. MLRO, Matera, Italy

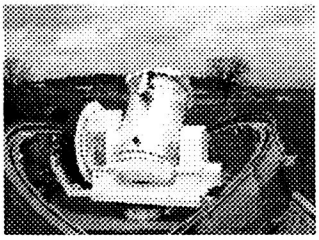

Fig. 4b. Zimmerwald, Switzerland

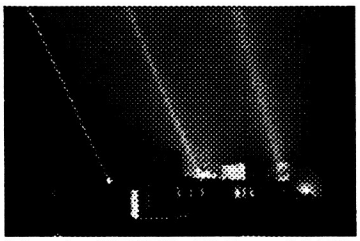

Fig. 4c. FTLRS, SLR, and LLR systems, Grasse, France

Asia. The data quality and quantity from the permanent Chinese stations (Shanghai, Changchun, Wuhan, Beijing, and Kunming) continue to improve. The Wuhan SLR station has been recently moved to a local site with better weather conditions. The Shanghai SLR station is scheduled for relocation to a less urban site later this year. Over the past couple of years, a mobile SLR system built by the Chinese Academy of Surveying and Mapping in Beijing has occupied sites in Lhasa and Urumuqi, as part of a national geodetic program. In Japan, the upgraded SLR station at the Communications Research Laboratory (CRL) in Tokyo is now operational (Fig. 5a). The new Global and High Accuracy Trajectory determination System (GUTS) SLR system is currently under development for NASDA with a planned deployment at Tanegashima next year.

Australia. MOBLAS-5, long established by NASA and Geosciences Australia (formally AUSLIG) at Yarragadee, Australia, continues to operate with exemplary performance (Fig. 5b). Operations at the new Geosciences Australia station at Mt. Stromlo were going extremely well until a catastrophic forest fire destroyed the site and much of the surrounding area. Reconstruction is now in the planning stages.

Fig. 5a. CRL, Koganei, Japan

Fig. 5b. MOBLAS-5, Yarragadee, Australia

Pacific and Africa. NASA, CNES and the University of French Polynesia have established SLR operations on the island of Tahiti with the NASA MOBLAS-8 (Fig. 6a). NASA has also relocated MOBLAS-6 to Hartebeesthoek, South Africa in cooperation with the South African Foundation for Research Development (FDR) to complete the first permanent Fundamental Geodetic Station in Africa (Fig. 6b).

Lunar Network. The lunar laser stations in McDonald Observatory in Texas and the Observatoire de la Cote D'Azur continue to operate. These stations are under great funding pressure, but a new lunar station being built in Apache Point, Arizona by the University of Washington and the new lunar capability at Matera should help to strengthen the network.

Fig. 6a. MOBLAS-8, Tahiti, French Polynesia

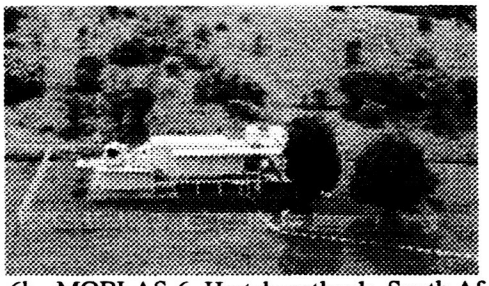

Fig. 6b. MOBLAS-6, Hartebeesthoek, South Africa

4. ILRS MISSION SUPPORT

Missions. The ILRS is currently tracking over twenty artificial satellites including passive geodetic (geodynamics) satellites, Earth remote sensing satellites (altimeters, SAR), navigation satellites, and engineering missions. The stations with lunar capability are also tracking the lunar reflectors. The evolution of SLR tracking over the last thirty years and projection into the near future is shown in Fig. 7. Satellites are added and deleted as new programs are approved by the Governing Board and old programs are completed.

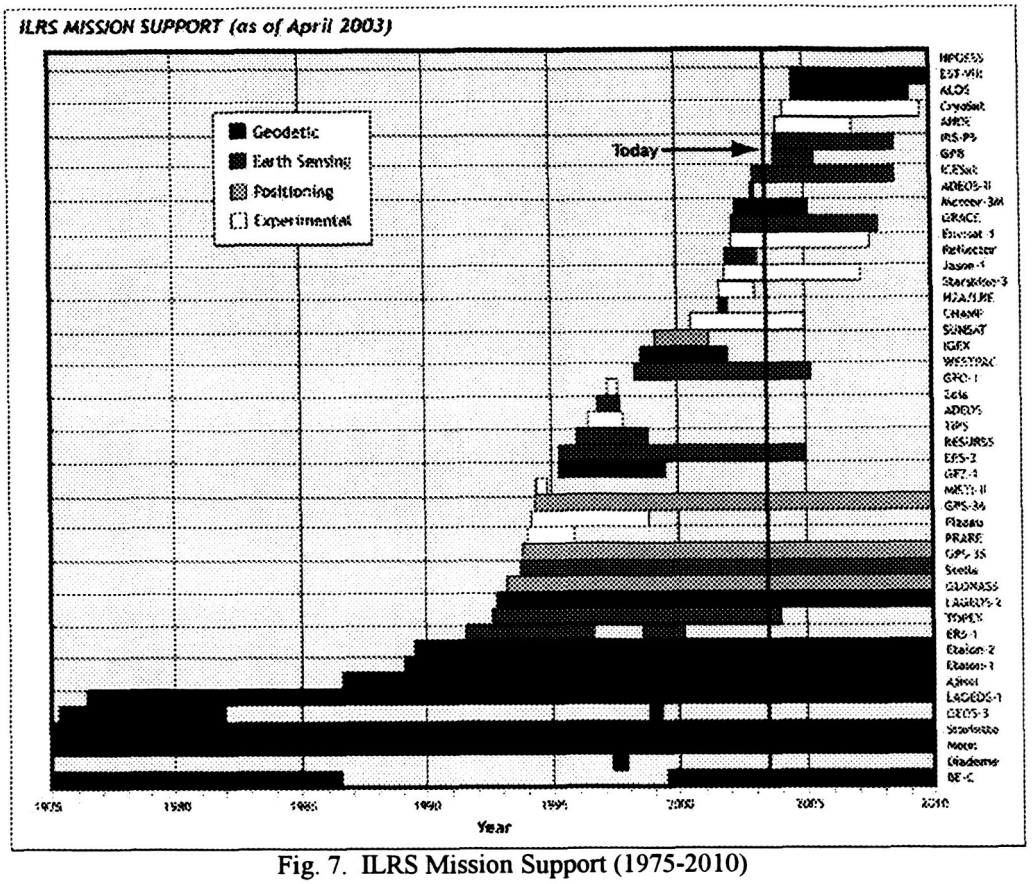

Fig. 7. ILRS Mission Support (1975-2010)

Several of the missions involved tandem orbits. The GRACE-A and -B satellites (Fig. 8a) are two identical spacecraft positioned thirty seconds apart in a low orbiting configuration to measure intermediate and short wavelength structure of the gravity field using satellite to satellite tracking. GPS and SLR provide POD for the GRACE mission. Jason-1 (Fig. 8b) is in a tandem orbit with TOPEX/Poseidon, originally separated by one minute in time, later moved into a six-minute separation. This configuration was adopted first to verify the Jason altimeter measurements and to then provide a wider swath of ocean topography measurements. GPS and SLR provide POD and altimeter calibration and validation. Envisat (Fig. 8c) is positioned in tandem orbit with ERS-2, separated by thirty minutes to provide periodic cross-validation for the altimeters and synthetic aperture radars on each of the satellites. The configuration is also being used to test INSAR concepts. DORIS and SLR provide POD for Envisat.

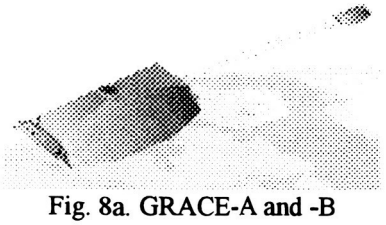
Fig. 8a. GRACE-A and -B


Fig. 8b. Jason-1

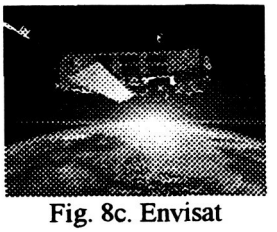
Fig. 8c. Envisat

Some tandem missions (e.g., Grace A and B) may be tracked on alternate passes at the request of sponsor. In response to tandem missions and general overlapping schedules, some stations are now interleaving to catch the beginning of the pass, closest approach, and the end of the pass (Fig. 9). An example of a productive day of tracking at Yarragadee is shown in Fig. 10.

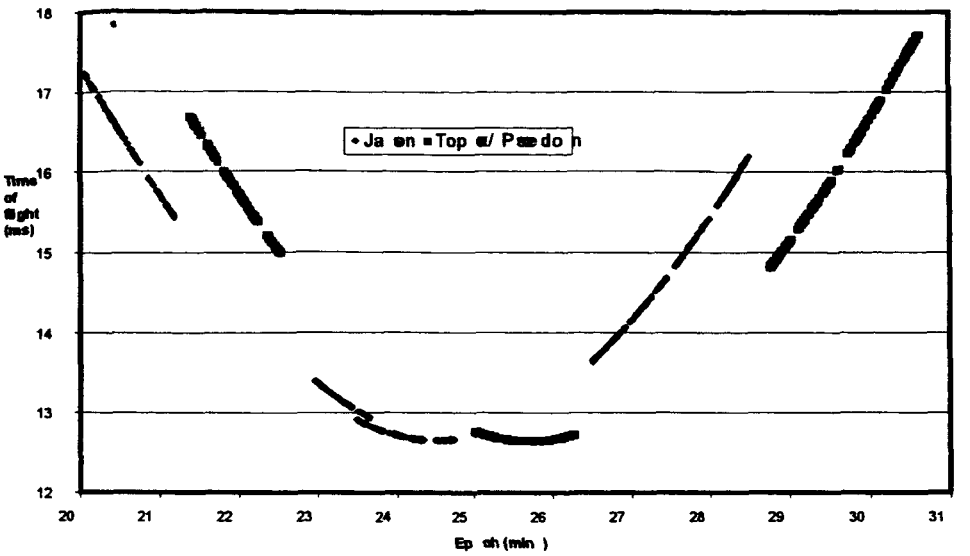

Fig. 9. Interleaved passes from Zimmerwald station

Some of the new missions were rather unique. The Russian Reflector satellite had retroreflectors over its nearly 1 1/2 meter length (Fig. 11a). Differences in the laser return time-of-arrival were used to interpret the orientation and dynamics of the satellite (Fig. 11b). The Reflector tracking support continued into early 2003.

Another missions, the Naval Research Laboratory's Tether Physics and Survivability satellite, TiPS (Fig. 12) with retroreflector arrays on two satellites separated by a 4 kilometer tether was tracked by SLR to study tether dynamics in space.

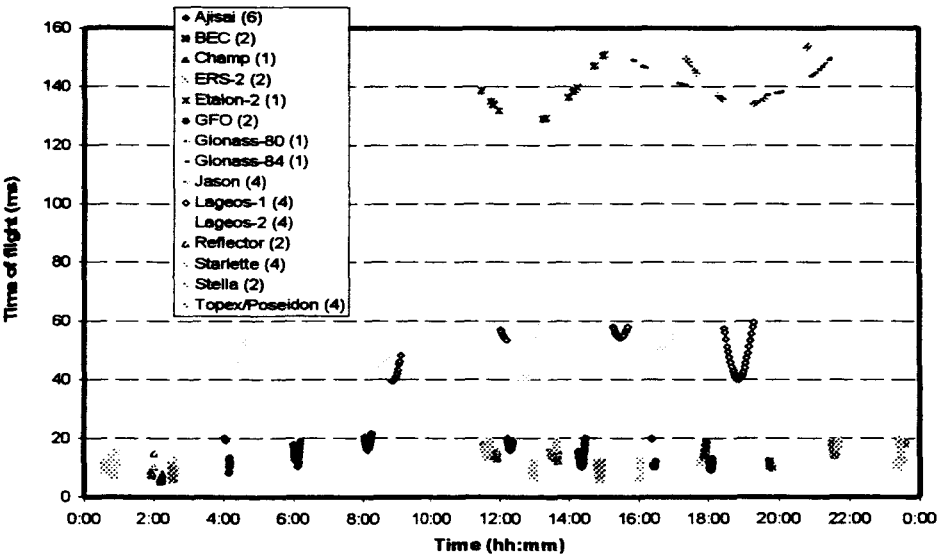

Fig. 10. An example of a productive day of tracking at Yarragadee

The Meteor-3M satellite launched by the Russian Space Agency carried an Optical Luneberg Lens consisting of two concentric glass balls of different indices of refraction with one half covered with a reflective coating. Experiments were conducted on the lens to test it as future retroreflector design. Although the tracking on Meteor-3M was planned as a six-week experiment, the immediate failure of the onboard GPS/GLONASS receiver following launch left the mission without routine tracking support for the on-board NASA Strategic Aerosol and Gas Experiment

(SAGE) which is measuring the vertical structure of the atmosphere. After this failure, the ILRS approved routine SLR tracking for the mission.

The ILRS also continues to track GPS and GLONASS missions for validation of the radio tracking systems in support of IGS activities.

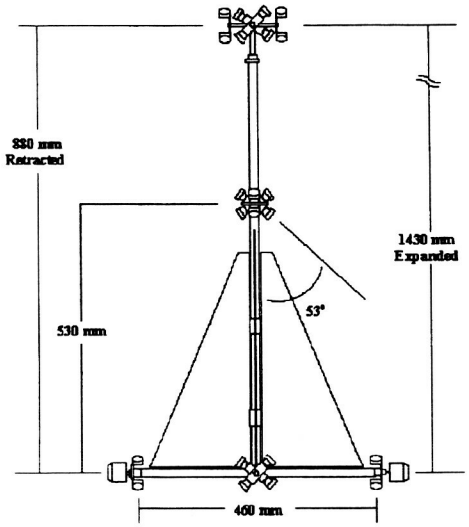

Fig. 11a. Schematic of Reflector Satellite

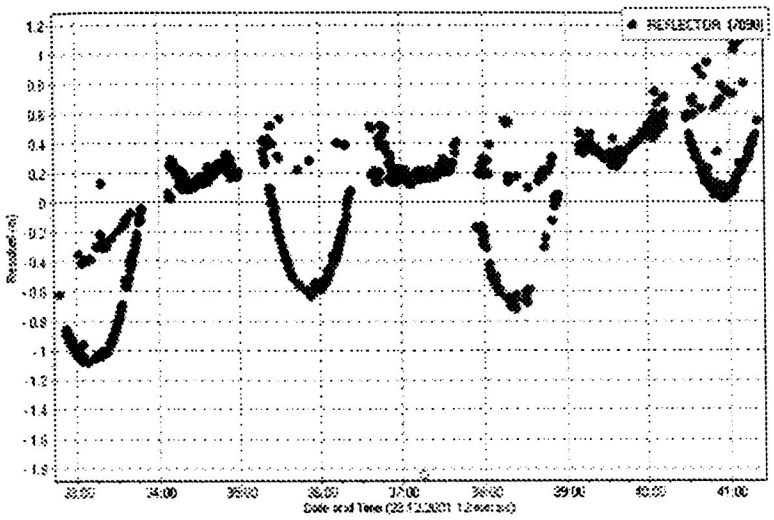

Fig. 11b. Range residual pattern observed at Yarragadee (Courtesy of Natalia Parkhomenko, RSA)

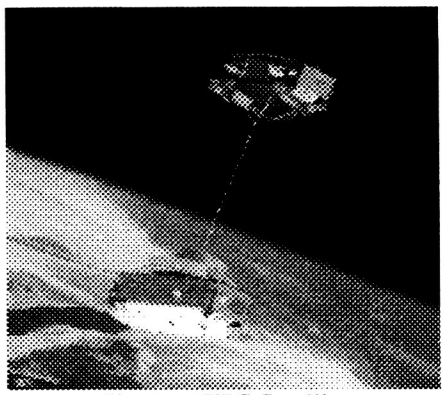

Fig. 12. TiPS Satellite

Tracking Priorities. The ILRS assigns satellite priorities as shown in Table 1, 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. Nominally tracking priorities decrease with increasing orbital altitude and increasing orbital inclination (at a given altitude). Priorities of some satellites are then increased to intensify support for active missions (such as altimetry), special campaigns (such as IGEX 98), and post-launch intensive tracking campaigns. Some slight reordering may then be given to missions with increased importance to the analysis community. Priorities provide guidelines for the network stations, but stations may occasionally deviate from the priorities to support regional activities or national

Table 1. ILRS Satellite and Lunar Priorities (as of July 2003)

Satellite Priorities

Priority	Mission	Sponsor	Altitude (km)	Inclination (degrees)	Comments
1	GRACE-A, -B	GFZ/JPL	485-500	89	Tandem mission
2	CHAMP	GFZ	429-474	87.27	
3	GFO-1	US Navy	790	108.0	Altimetry; no other tracking technique
4	Envisat	ESA	796	98.6	Tandem with ERS-2
5	ERS-2	ESA	800	98.6	Tandem with Envisat
6	Jason	NASA/CNES	1,350	66.0	Tandem with TOPEX
7	TOPEX/Poseidon	NASA/CNES	1,350	66.0	Tandem with Jason
8	Starlette	CNES	815-1,100	49.8	
9	Stella	CNES	815	98.6	
10	Meteor-3M	IPIE	1,000	99.64	
11	Beacon-C	NASA	950-1,300	41	Upgraded from campaign to ongoing mission (Jan-02)
12	Ajisai	NASDA	1,485	50	
13	LAGEOS-2	ASI/NASA	5,625	52.6	
14	LAGEOS-1	NASA	5,850	109.8	
15	Etalon-1	Russian Federation	19,100	65.3	Campaign extended indefinitely
16	Etalon-2	Russian Federation	19,100	65.2	Campaign extended indefinitely
17	GLONASS-89	Russian Federation	19,140	65	Replaced GLONASS-86 (Mar-03)
18	GLONASS-87	Russian Federation	19,140	65	Replaced GLONASS-88 (Feb-02)
19	GLONASS-84	Russian Federation	19,140	65	Replaced GLONASS-79 (Feb-01)
20	GPS-35	US DoD	20,100	54.2	
21	GPS-36	US DoD	20,100	55.0	

Lunar Priorities

Priority	Retroreflector Array	Sponsor	Altitude (km)
1	Apollo 15	NASA	356,400
2	Apollo 11	NASA	356,400
3	Apollo 14	NASA	356,400
4	Luna 21	Russian Federation	356,400
5	Luna 17	Russian Federation	356,400

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. Missions are added and deleted from the tracking roster as requirements are requested and fulfilled.

Future Missions. A number of new missions requiring SLR support for POD and instrument calibration and validation are scheduled for launch over the next two years (See Table 2)

Table 2. Upcoming missions requesting support by the ILRS

Mission	Sponsor	Scheduled Launch	Application
GP-B	NASA, Stanford	Nov. 2003	Check on theory of relativity through precise gyroscope measurements
STARSHINE-4/5	NRL, NASA, others	Mid 2004	Atmospheric drag measurements; student involvement to study atmospheric density
CryoSat	ESA	May 2004	Ice surface altimetry to study changes in ice thickness
ANDE	NRL	Late 2003	Digital communications transponder for amateur science
ALOS	NASDA	Aug. 2003	Microwave and optical sensing of the environment
ETS-VII	NASDA	2004	Test of new geosynchronous satellite bus
NPOESS	NOAA, NASA, DoD	2013	Sea surface height

5. NETWORK PERFORMANCE

SLR and LLR use short pulse lasers to measure the distance to passive targets on satellites and the Moon. The measured range is the roundtrip travel time corrected for optical refraction and spacecraft center of mass. The prime data product from the ILRS stations is normal points, which are full rate ranging data averaged over time intervals ranging from fifteen seconds to five minutes depending upon satellite altitude. Higher satellites have longer normal point intervals. Data are archived and available to the user on a pass by pass basis.

The ILRS Central Bureau routinely assesses the performance of the network stations in terms of data quality, quantity, and timeliness, and issues a quarterly report card, which is posted on the ILRS website. Also available is a more detailed look at the data from each station with historical calibration and other diagnostic information.

Since the inception of the ILRS, the data yield of the network continues to improve (Fig. 13) as stations implement more automated procedures and new satellites are added to the tracking roster. As shown in Fig. 14, most ILRS stations now provide normal point data with a precision of a few millimeters. Data from the global network are now available on an hourly basis from the ILRS data centers.

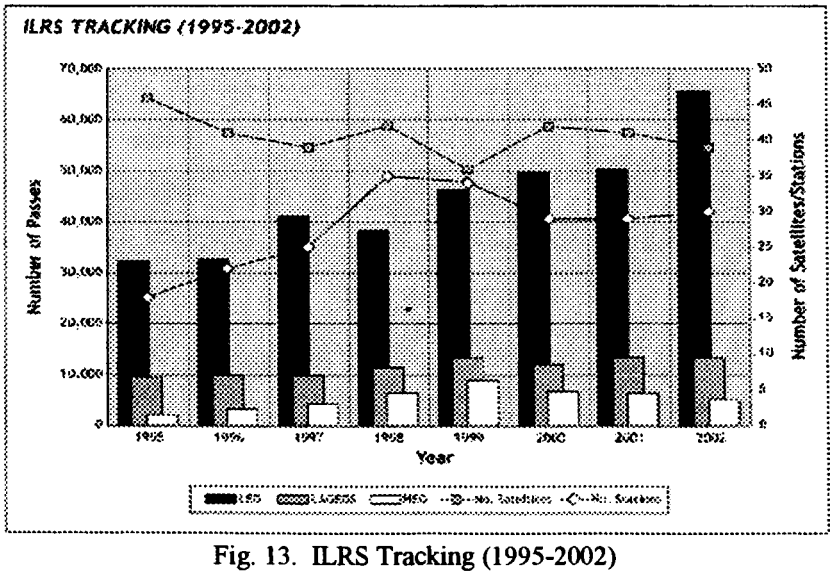

Fig. 13. ILRS Tracking (1995-2002)

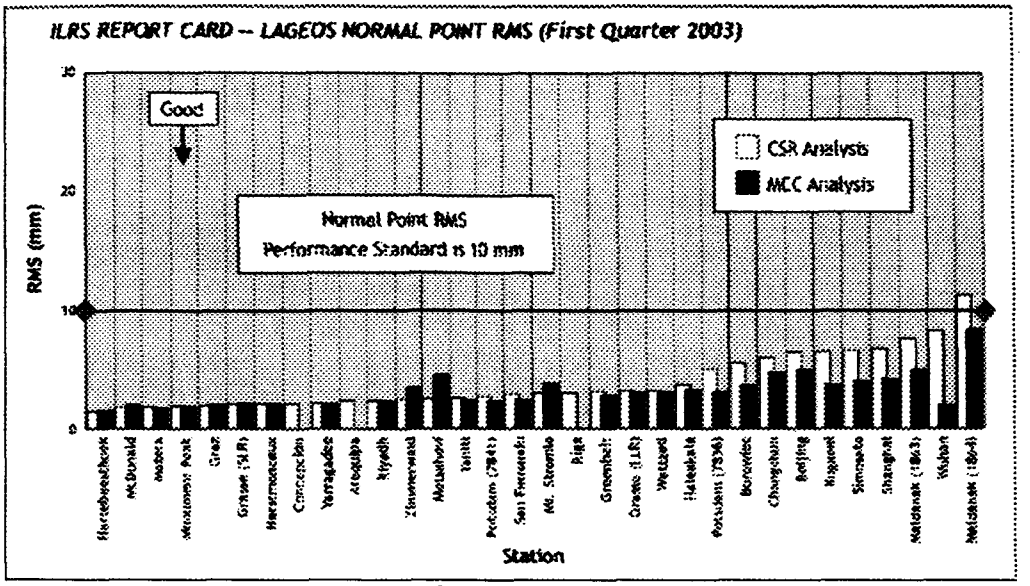

Fig. 14. LAGEOS Normal Point RMS (2003)

In some cases the precision has been high enough that stations can observe intricate details in the dynamics of LAGEOS. Fig. 15 shows measurements of the spin down rate of LAGEOS II as determined at the MLRO at Matera using spectral analysis of the laser return distribution.

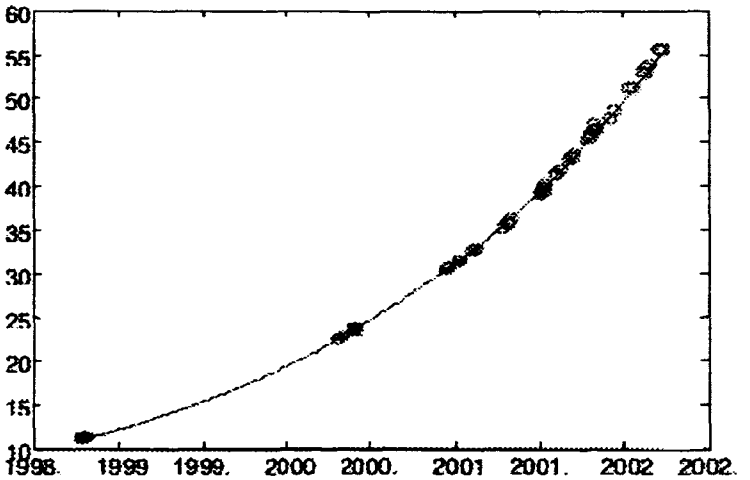

Fig. 15. LAGEOS Rotation Period (in seconds) Observed at the MLRO at Matera (Courtesy of Dr. Giuseppe Bianco, Colombo Center for Space Geodesy at Matera)

6. MEETINGS

The ILRS holds its General Assembly twice a year. All of the Working Groups traditionally meet at this venue. International Workshops on Laser Ranging are also held biannually. Reports on past meetings and information on future events can be found on the ILRS website. The ILRS also holds workshops to focus on ranging technology and current issues effecting ranging and data throughput. The next workshop will be held in Koetzting, Germany on October 28-31. The program for the workshop can be found under the Laser Workshop 2003 link at the website http://www.wettzell.ifag.de/.

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