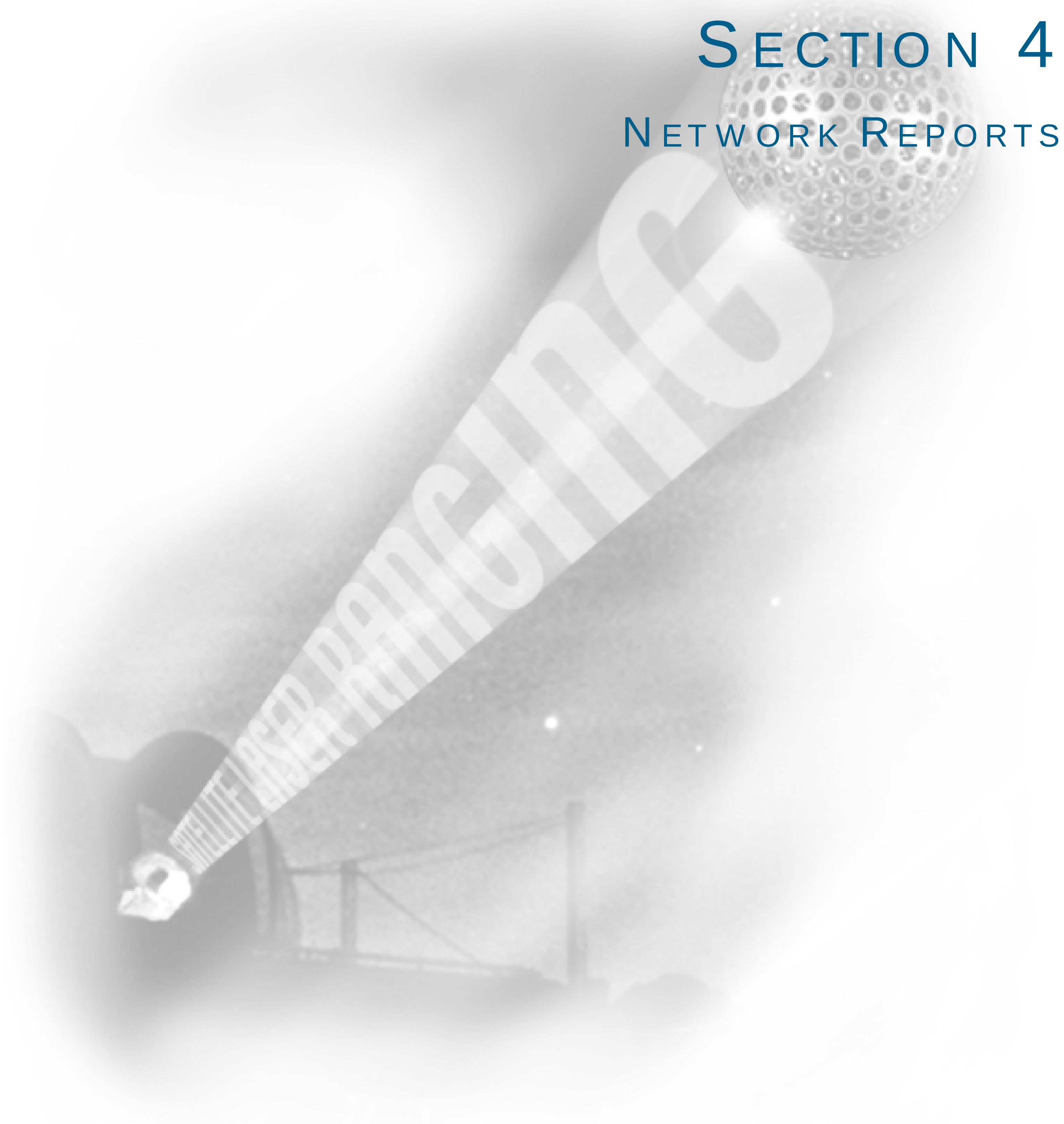
SECTION 4

NETWORK REPORTS



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SECTION 4 - NETWORK REPORTS

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

1. EUROLAS Network encompassing the European stations
2. NASA network encompassing North America, and some stations in South America, South Africa and the Pacific
3. Western Pacific Laser Tracking Network (WPLTN) encompassing Japan, China, Eastern Russia and Australia

There is some overlap among the regional networks due to cooperating agreements, equipment loans and historical operating arrangements.

4.1 EUROLAS NETWORK

George Kirchner, *Australian Academy of Sciences*

Graham Appleby, *NERC Space Geodesy Facility*

INTRODUCTION

EUROLAS, the European sub-network of the ILRS tracking network is a major contributor both to the global SLR tracking effort, and to the advancement of SLR technology and scientific value of the data. The eighteen stations that make up the sub-network (see Figure 4.1-1) have contributed during the period of this Report some 40% of the global tracking of all satellites and feature most of the different technologies in use globally for SLR work. Some systems use high-energy laser systems and MCP detectors, others use and continue to improve the Single Photon Avalanche Diodes that were developed within Europe, and some work strictly at the single-photon level of return. This disparate nature of the stations inevitably means that there exists a variation in tracking capabilities and quality across the sub-network. This variation in capability has, however, been recognized in recent years and some prioritization of targets has been decided upon at the EUROLAS level. For instance, the large and powerful systems in operation in Wettzell and Grasse are particularly suited to tracking high-altitude satellites such as the two GPS vehicles that are fitted with retro-reflectors. Other less capable systems concentrate on the equally important, but less demanding, low Earth satellites such as ERS-2 and TOPEX/POSEIDON. The very clustering of the EUROLAS stations has caused some criticism in the context of a global tracking network that is far from homogeneously distributed; the proposal that some systems be re-located to other less well-represented parts of the globe has frequently been voiced.

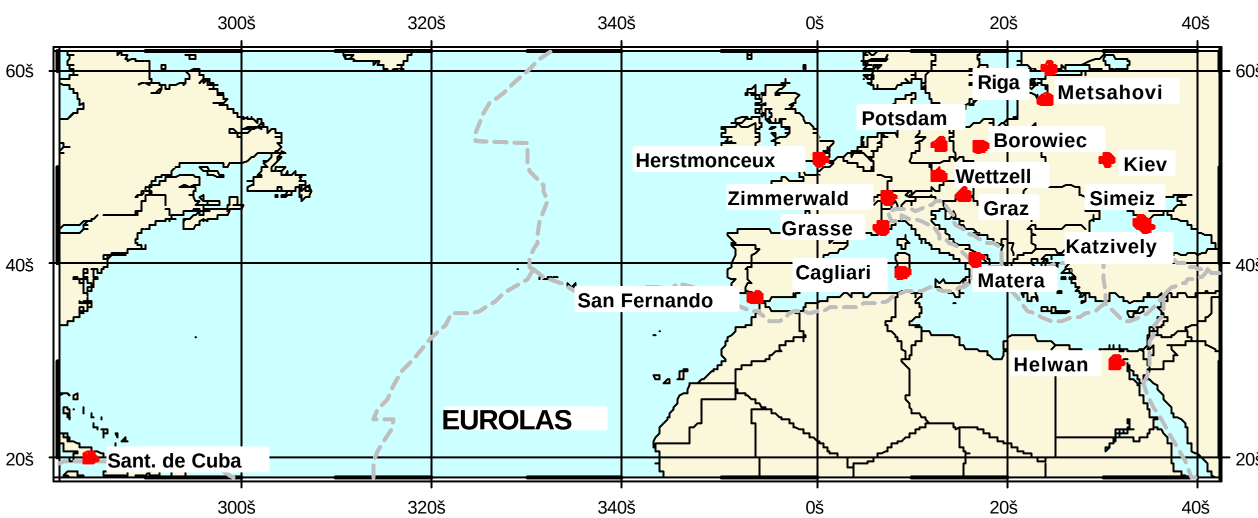

Figure 4.1-1 Eighteen Stations That Make Up the EUROLAS Sub-network

However, the clustering itself can also be regarded as a strength. Several altimeter missions such as the ERS satellites have benefited from concentrated SLR tracking in association with campaigns within Europe to calibrate their altimeters, and plans are in train similarly to calibrate the altimeter of the ESA mission ENVISAT due for launch in 2001. The close clustering of the stations also represents a unique opportunity to crosscheck the quality of each of the stations by carrying out analyses of simultaneous tracking data. The following sections of the EUROLAS report include a brief history of the origins of the Sub-network, an overview of its organization and services, and status reports from many of the stations themselves.

ORGANIZATION

The EUROLAS Consortium itself was founded in 1989 during the 7th International Workshop on Laser Ranging Instrumentation in Matera after a proposal discussed at a meeting of European laser station representatives in Paris earlier in the same year. The main purpose of the consortium originally was the representation of the European SLR groups and dedicated analysis centers towards international organizations like NASA, ESA, CSTG, Interkosmos, and the coordination of activities with respect to operations, priorities, distribution of tasks, etc. It was recognized that the European network of laser stations "serves as one continental observatory in support of programs of a global nature", as can be read in the report about the Paris meeting.

The EUROLAS Board consists of the representatives of all member organizations and an elected Executive of at least a chairperson and a secretary. The Terms of Reference can be found e.g. at the EUROLAS Data Center (EDC) web site at:

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

The contribution of the EUROLAS Data Center itself to the Annual Report can be found in the Data Center section of the Report and the NERC contribution below is a summary only of its report as an Associate Analysis Center.

EUROLAS President: W. Gurtner *EUROLAS Secretary: W. Seemueller*			
A. Banni	CAGLIARI	M. Medvedsky	KIEV
G. Bianco	MATERA	R. Neubert	POTSDAM *(Follower Ludwig Grunwaldt)*
J. del Pino	SANT. De CUBA	M. Paunonen	METSAHOVI
J. Garate	SAN FERNANDO	F. Pierron	GRASSE
W. Gurtner	ZIMMERWALD	S. Schillak	BOROWIEC
Y.E. Helali	HELWAN	W. Schlueter	WETTZELL *(Armin Broer/TIGO, U. Schreiber/WLRS)*
G. Kirchner	GRAZ	W. Seemueller	EDC
Y. Kokurin	KATZIVELY	L. Shtirberg	SIMEIZ
K. Lapushka	RIGA	R. Wood	HERSTMONCEUX
J.-F. Mangin	GRASSE/LLR		

Table 4.1-1 List of Delegates for the EUROLAS SLR Stations

JOINT EFFORTS OF THE NETWORK

Daily Quality Check

As an initiative some years ago the EUROLAS network agreed regularly to monitor the quality of LAGEOS and LAGEOS-II range data from the global network, and in particular to exploit the strength of the EUROLAS cluster of stations to form short-arc orbital improvements and thus potentially detect system bias at the 10mm level. This procedure was automated and implemented on a daily basis in a valuable collaboration between the UK NERC Space Geodesy Facility and the Department of Satellite Geodesy, Austrian Academy of Sciences, Graz. Each day presented on the NERC SGF website at:

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

are plots of normal-point range residuals from six-day orbital solutions for the two satellites for each station in the global network. Currently the post-solution residual RMS for these solutions is about 20mm, and the plots serve to provide a rapid check on the presence of outliers in the tracking data, as well as a quick daily check on network productivity. Then are determined which, if any, passes during the six days have been tracked simultaneously by more than two EUROLAS stations, and for those a short-arc orbital correction is computed. The residuals from this improved orbit give a good indication of the relative tracking quality of the stations, at a level of 10mm or so and again are presented daily in graphical form on the website.

Predictions and Time Bias Functions

The NERC Space Geodesy Facility computes two main prediction products, medium-term and daily. On a daily basis predictions are computed for most of the laser-tracked satellites including in addition the GLONASS satellites in support the IGEX-98 tracking campaign in a collaboration with the CODE, Berne, group. All the predictions are presented in the standard Inter-range Vector (IRV) format. Access information and the full list of satellites for which predictions are available is given on the official ILRS website. Time bias functions applicable to most of the available prediction sets are computed hourly using the latest observations from the network. Access to these functions is hourly via local ftp or daily by email from EDC.

Near-Realtime Status Exchange

In order to help exchange status information such as time biases between the European Laser stations in near realtime, a corresponding system has been defined and installed at a server in Zimmerwald. The basic principles are as follows:

Each participating laser station generates a one-line status file periodically (e.g. every 30 seconds) and sends it by ftp to the central server.

The server concatenates all available files into one resulting summary file, which is downloaded by the stations for display.

Each laser station may also upload a short message file to the server containing a message to be appended to the summary file for a maximum of 30 minutes.

The server also waits on a specific port for telnet connections and outputs the status file to these connections, too.

Example:

Herstmonceux	1998-11-30 09:55:57	LAGEOS2	CUR	345	DAILY	0.001
Potsdam	1998-11-30 09:55:23	LAGEOS2	CUR	221	CSR005	0.021
Zimmerwald	1998-11-30 09:55:26	LAGEOS2	LST	570	CSR005	0.023
Zimmerwald	1998-11-30 09:55:56	Ajisai	CUR	164	DAY001	-0.001

Currently 5 or 6 stations (Grasse SLR, Herstmonceux, Potsdam, Wettzell, Zimmerwald; Graz is working on the setup) routinely use this status exchange. It is thus possible to “learn” from a station the current time bias of a satellite, leading to an almost immediate acquisition, provided the two stations used the same IRV set for the predictions. Observers also like to see what’s currently happening at the other stations of the European network.

Future improvements will include a more direct information exchange using basic TCP/IP send and receive routines to avoid the large overhead of the ftp connections.

More information can be found in SLRMail 372, which can be downloaded from the EDC at:

ftp://ftp.dgfi.badw-muenchen.de/pub/laser/messages/slrmail/slrmail.372

Organization of Colloquium on SLR-Calibration Issues

This colloquium was organized by the Wettzell group and took place during the “Conference on Laser Radar Techniques” held in Florence, Italy, on September 23-24, 1999.

The largest remaining contribution to systematic error for range measurements to satellites and the Moon is related to the calibration process of the various ranging systems. Unlike in other space geodesy techniques we find a large variety in the laser ranging system design. Many systems have been developed independently over the last three decades, so that there is no standardization in methods or daily practice. This colloquium reviewed all the involved procedures and hardware arrangements in order to work out a standard set of recommendations for an optimized calibration process. It was specifically intended to keep a closed loop between the user of the data product and the data generating stations.

The colloquium was separated into two major sections, namely procedures and technology. The session about the procedures covered the areas analysis, calibration schemes, target design, local survey, data treatment and signal signatures. Especially the latter two subjects roused an extensive discussion, showing that these issues were by far not handled uniformly and had room for improvements at many stations. But also the subjects target design, local survey and calibration schemes stimulated a lively discussion and provided a good overview of the various practices in the community.

The second session on SLR technology dealt with the various critical components of an SLR system. All the major elements that influence the time of flight measurement were reviewed. In fact it became clear that most stations are working within the same limits of accuracy. Unlike in the data treatment section there was relatively little room for improvement for most stations here. However some differences in operational practices for the calibration became apparent and were discussed.

A more complete summary of this colloquium is currently under preparation and will be made available to the community as an independent document.

Assistance and technical help between EUROLAS SLR stations

As examples of such activities, we mention here the supply of hardware on a long-term loan basis between various SLR stations. For the SLR station Riga, Peter Sperber has initiated this via EUROLAS recently, and the RIGA station is being supplied with CF discriminators, PMT's, and, hopefully, with some good working oscilloscopes from Graz and other stations. Metsahovi is about to start testing a microchannel plate detector borrowed from Graz and Graz is successfully using a Laser dye supplied from Potsdam.

SLR STATION REPORTS

GRASSE

LLR GRASSE/Satellite Laser Ranging

This report is about the SLR activities of the LLR station in Grasse; a dedicated report for the observations of the Moon appears in the LLR Section of the Annual Report.

The LLR station of Grasse (France) was fully operational in 1999 for the observations of high altitude satellites, although the priority remains on ranging of the lunar retroreflectors. Observations were regularly carried out on the two LAGEOS, GPS 35-36, Etalon and the GLONASS constellation. Many observations were taken during daytime, which is a distinctive mark of this facility. Altogether this yielded 4000 normal points for the two LAGEOS and about 3500 for the other targets, which is very satisfactory, given the scientific priority and the limited staff in charge of all the instrumental and logistical aspects and the observations. Several kinds of analyses (e.g. high precision orbitography, long period change in parameters of geophysical interest, long arc technique) are made by scientists of CERGA based on the laser data.

The station has been developed and optimized with the ranging on the Moon in mind and just recently adapted for the satellites. The width of the laser pulse, between 250 and 300 ps, is not optimal for the satellites and remains the major source of scatter in the raw data. In addition in the case of LAGEOS there are operational shortcomings due to its relatively short range meaning that no real-time calibration can be performed, which is the norm for the other distant targets.

Short-term plans are to keep on with this dual exploitation of the instrument and also to take advantage of the two tracking stations on the same site to improve knowledge of instrumental bias.

SLR GRASSE/CERGA: Fixed Station

The Grasse SLR system has operated continuously during 1999 without major failures. Observation priorities have been fixed in agreement with ILRS recommendations but excluding high passes (GPS, GLONASS); the nearby LLR station is tracking these satellites. A total of 2,755 passes (including 406 LAGEOS) have been observed, giving 51,000 Normal Points with a 2 mm RMS and a long term estimated stability of 13 mm (range bias adjustment with CSR solution). A very precise colocation experiment has been done between the fixed SLR and LLR station with common LAGEOS passes over several months; regular absolute gravimetric measurements are now being made at the site twice a year in order to establish correlations between potential ground motions observed with different techniques.

An important point to underline here is the recently improved efficiency of the operations due to the "Real Time Exchange" system used by most European stations; it is very helpful to fix the time biases from up-to-date results from other systems tracking the same spacecraft.

GRASSE/CERGA Ultra Mobile Laser system FTLRS

The year 1999 has been an important upgrade time for the Ultra Mobile French Transportable Laser Ranging System (FTLRS) in preparation for the 2000/2001 Jason calibration mission. In this timeframe, different technical problems had to be solved with the goal of reaching an accuracy of better that 1 cm. These include:

- Tests and measurements concerning time variations of the detector signal through the slip rings; replacement by a coaxial cable;
- Tuning the design of the laser to be operated in the green and with a pulse width of 35 ps;
- Tests of different SPAD detectors; installation in the very small FTLRS mount during October and November of a Time-Walk-Compensated SPAD (chip from Prague), with electronics especially designed by the Graz group.
- Due to the compact design of the FTLRS, the very serious problem of a high amount of backscattered light entering the detector during laser firing is being solved with an electro-optical liquid crystal shutter;
- Installation difficulties, such as thermal regulation of the shutter, free space for electronics inside the mount, etc.

The upgraded system should be ready for testing in early 2000. These include tests to replace the GPS-slaved Rubidium clock and colocation with the fixed SLR and LLR CERGA stations hopefully in spring/summer 2000.

SLR GRAZ

SLR Graz tracked about 4300 Passes during the year 1999; the list of satellites ranged from GFZ up to GPS 35/36; all satellites (including GPS) were tracked during day and night, 7 days per week. Besides this routine tracking, considerable work was invested into some upgrades, as follows.

Software:

Inclusion of a Real Time Scheduler, showing the list of actually running passes;

Implementation of Sun avoidance routines for the telescope daylight tracking;

In addition to the Automatic Range Gate and Automatic Tracking, Automatic Time Bias Calculations and Adaption (all for Real Time Tracking) were added.

Hardware:

Upgrade for Start Pulse detection: New Detection Scheme with improved stability;

Time and Standard Frequency now via an HP 58503A GPS Receiver (Graz Time Station has stopped this service);

Implementation of a new Start/Stop Pulse Distribution Unit, with six outputs for each channel, for Counter Cluster, tests etc. The unit has < 1 ps/°C drift, adding < 1 ps RMS to the total jitter;

Two Dassault Event Timer Modules, plus 1 Clock Module (specs: <2 ps RMS, 2.5 ps linearity) have been ordered (delivery expected spring 2000); hardware and software work is underway to build a complete new event timer system for the Graz SLR around these modules.

SLR HERSTMONCEUX, NERC Space Geodesy Facility, UK

The Herstmonceux site features the SLR single-photon system, an Ashtech GPS receiver contributing to IGS and a 3S Navigation GLONASS receiver all of which are operated on a continuous basis. SLR tracking of all satellites has continued day and night throughout the year. The single-shot precision achieved during calibration ranging is about 8mm, and that from ranging to LAGEOS is about 16mm. All ranging measurements are carried out at the single-photon level of return, and the long-term stability of the system appears to be excellent.

A C-SPAD detector was purchased late in 1998 and, after tests and re-adjustment at Graz to tune it to the laser pulse length, began operational use in 1999 March. Results of tests on the detector, together with extensive experiments to intercompare timers, were reported at the Europto meeting in Florence in September.

Trials using a calibration target attached to the end of the telescope have succeeded in overcoming SPAD gating problems and a fully engineered version is planned next year.

Replacement of the final mirror mount in the emitter coude train with a piezo-driven platform has enabled the correction of the beam alignment under computer control. Tests are currently underway to use TV systems to view both the beam and bright stars in daylight with the aim of developing algorithms for realtime corrections to telescope pointing and beam alignment (to compensate for daytime heating) with the aim of bringing daytime performance in line with that at night.

SAC - Astronomical Station of Cagliary, Italy

Instrumentation at the site includes the Fixed SLR Station and the GPS Permanent Station, with operational DGPS and Time Keeping/Synchronization using Standard Caesiums, GPS and Ajisai common-view. The SLR system includes a 10Hz Italian Quanta System Nd-YAG SFUR laser working at 532 nm with a 100ps pulse of energy 80mJ. The time interval counter is a HP-5370B and the detector is a Hamamatsu R943-02 PMT.

The SLR system achieves day and night tracking of Low Earth Satellites including Ajisai, Starlette and Topex/Poseidon, and in addition nighttime tracking of the LAGEOS and GLONASS satellites. The current single-shot calibration precision (1-sigma) is 250ps (35mm), with epoch accuracy of 1 µsec.

Upgrades to be carried out in the near future include the replacement of the detector with a MCP-PMT Hamamatsu R5916U-50, replacement of the telescope encoders (22 bit = 0.5 arcsec) and the telescope motion gear (0.1-20 mrad/sec). The software will also be upgraded from the present C and DOS system to C++ under Linux.

Current research activities include co-location techniques; Geoid and local networks ties; and time synchronization.

SLR MATERA: SAO-1, MLRO

During 1999, the old SAO-1 SLR system, operational at the Center for Space Geodesy of the Italian Space Agency, Matera, Italy, observed the largest number of passes since its installation in 1984, a total of 1725 passes on 12 target satellites. This was the last fully operational year for SAO-1, which will soon be replaced by the Matera Laser Ranging Observatory (MLRO)

The development of the MLRO is now on its final phase. In 1999, the observatory building was completed, the dome was installed and, at the end of the year, the system was shipped from the USA to Matera. The system is expected to be fully operational by July 2000.

Based on a 1.5 m reflecting astronomical telescope, the MLRO is a highly evolved SLR/LLR observatory, featuring a few mm range precision on LAGEOS (<1 mm RMS on ground targets), two color capability (532 nm and 355 nm), MCP-PMT and streak camera echo detection, imaging devices, on-line documentation and high level of automation.

Figure 4.1-2 shows the 1.5 meter MLRO telescope through the slit of the 9.5 meter dome. The aircraft detection radar's white dome is visible on the roof of the old SLR system.

SLR METSAHOVI

The configuration of the Metsahovi SLR station is very much the same as that reported in the 11th laser workshop in 1998. Some small changes have however been made, including the addition of a laser preamplifier, the addition of a HP5370B for comparison with the Riga counter and alterations so that the start pulse is taken after the mode-locked oscillator. A Hamamatsu MCP detector has been received from Graz for tests; the mechanical installation is ready, but the necessary gating electronics are in proocess.

There have been many problems with the meteo barometer. The Ashtech Z18 has suddenly stopped working (as it did about one year ago), ceasing data on GPS and GLONASS. Also much time has been spent comparing the system counters in an attempt to find which one represents the best linear system.

SLR SAN FERNANDO

After the new dome was installed during the 4th quarter of 1998 the SLR instrument was placed in a new position, 35 cm over the old one. The 1st quarter of 1999 was spent working on hardware and software to minimize the noise and to improve the quality of the observations. A new computer was installed to control the telescope tracking, and the cables from the control system to the telescope were changed. The telescope mirrors were recoated, and tracking was resumed in mid-April. During the remaining nine months of the year, 1916 LEO passes and 428

LAGEOS passes were tracked, which for each is well over the full-year ILRS baseline goal. From the beginning of the tracking period efforts have continued to improve the quality of the work. A new, closer calibration target has been installed to minimize atmospheric refraction dependence. A C-SPAD detector is planned for installation during the spring of 2000.

SLR HELWAN

The Helwan site is an important station in the SLR Network; it is still the only SLR station on the African Continent. Since June 1998 the station has been in year-round operation. The station fulfilled the ILRS Performance Standard for LEO satellites in 1999, having tracked 1331 LEO passes.

Figure 4.1-3 Helwan SLR Station

Several hardware upgrades have been carried out during the year, as follows.

A DIGIQUARTZ MET3 System has been installed. A Stanford SR620 Counter is now used for time interval measurement.

Time and frequency for the station originates from an HP58503B GPS Time and Frequency Receiver. A new Ground Target Calibration Scheme using a 2D hollow retroreflector has been installed.

The joint SLR Station Helwan is operated by NRIAG: National Research Institute of Astronomy and Geophysics, Cairo Helwan; Prof. Y.E. Helali/Prof. M.Y. Tawadros. Contact information is:

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nriag@frcu.eun.eg	CTU FNSPE Czech Techn. Univ. in Prague, Fac. of Nuclear Sciences and Physical Engineering;
novotny@troja.fjfi.cvut.cz	Assistant Prof. A. Novotny

SLR ZIMMERWALD

In 1995 the laser ranging system was dismantled and replaced by a new telescope and a new laser system. The 1-m telescope can be used for optical (CCD) astronomy, as well. The laser system is the first Titanium-Sapphire laser ever used for satellite tracking.

Since 1997 the new system has been operating on a routine basis. Two breaks of about two months were needed for recoating of the mirrors and for maintenance/repair of the laser system. Problem areas were found to be environmental problems (condensation), lifetime of the silver mirror coatings and of the pump diode of the laser oscillator, and high noise levels during daytime operation.

A high level of automation allows for a relatively short training period of the operators. Full remote control of the ranging system can be used for debugging and training purposes.

Next steps will be improvement of the ranging accuracy, use of the primary wavelength of the laser (846 nm) for ranging, and improvement of the automation.

SLR BOROWIEC

SLR Borowiec was operational 7 days per week throughout 1999 without important system modifications. It achieved returns during nighttime from all the satellites in the ILRS tracking program. The number of successful passes was the best in the history of the SLR station, with 1056 passes tracked during the year. The accuracy of the system remains on the same level as before, with a normal point precision of 6mm. In addition to the SLR system, the Borowiec site is a permanent IGS station (BOR1), operating a Turbo ROGUE SNR 8000 receiver and contributing hourly data to IGS. A new antenna was installed on June 1, 1999. The station also participated in the IGEX campaign, using a 3S Navigation GPS/GLONASS receiver, which continues in permanent operation. Full station parameters are on the Borowiec web page at:

http://www.cbk.poznan.pl/~laser/bor1.html

Figure 4.1-4 Borowiec SLR Station

Contact: Dr. Stanislaw Schillak: sch@cbk.poznan.pl

SLR POTSDSAM

SLR station Potsdam-2 (No.7836) has been operated routinely since 1993[1]. Observations using this system will be continued until successful completion of the test phase of the new station, which will be sited about 300m away at the GFZ main building (Figure 4.1-5).

Figure 4.1-5 Building for the new SLR station at GFZ Potsdam. The laser transmitter is located inside the tower below the dome's platform whereas the control and measuring electronics is contained in a laboratory of the neighboring main building.

The new system is based on an unconventional bistatic telescope system[2], (Figure 4.1-6), and an actively mode-locked Nd-YAG laser. This laser produces pulses of 10 mJ in 30ps and can be switched between single pulse and semitrain operation under computer control.

Figure 4.1-6 Close up view of the telescopes in the status of assembling, without optics. Foreground: Transmitter (partially opened) without electronic unit. Background: Receiver, with on the right hand the electronic control unit (black box in the housing).

References

[1] http://www.gfz-potsdam.de/pb1/SLR/slr.htm

[2] Proc. Conf. on Laser Radar Techniques III, Florence, Sept.20-21, 1999

Wettzell Laser Ranging System

The main aim in 1999 was to build a new control system. Figure 4.1-7 shows the modular structure of the new control unit and the communication paths between the modules. The telescope control unit and the scheduler server are python programs based on a C-library whereas the measuring unit is a LabVIEW program (the front panel is shown in Figure 4.1-8). The communication is mainly based on TCP-IP connections between the computers and RS-232 interfaces between the measuring computer, the event timer and the radar, respectively. The new event timer consists of four Dassault timing modules and one clock module. The database is written in PostgreSQL. Here the IRV and timebias function parameters are saved together with a list of the actual satellites, information of the station and parameters of the measuring system. The tables in the analysis archives contain the history of the calibrations and the normal points of tracked passes.

The new control system will soon be ready to take over the routine ranging measurements.

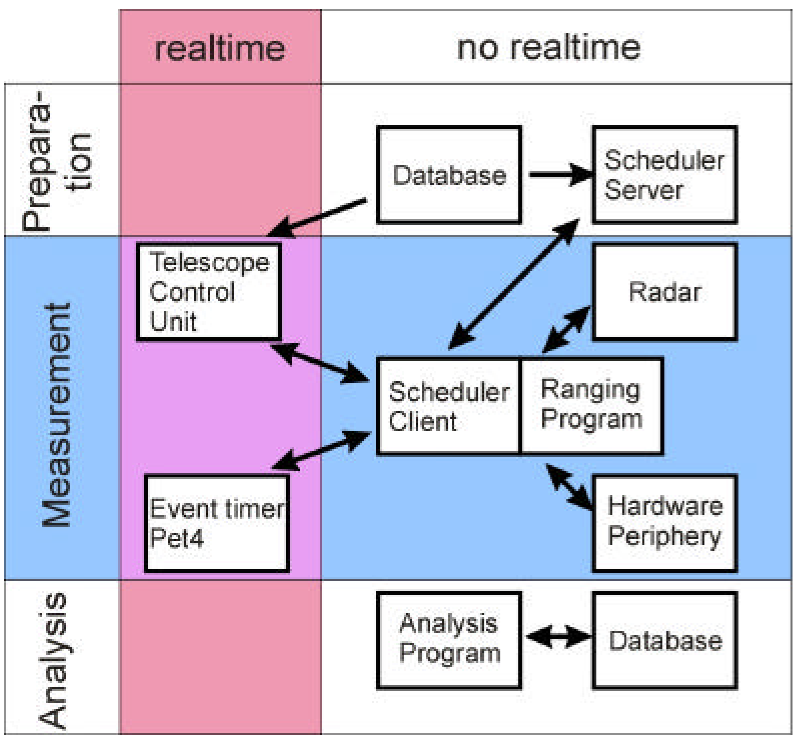

Figure 4.1-7 Scheme of the construction of the new control system. It has a modular structure that separates units needing real-time from the ones that don't depend on an exact timing. The arrows indicate the communication paths between the units.

Other activities underway concerned the timewalk effect in APD's. As reported at the Europto meeting in Florence in September, an investigation was carried out into an electronic compensation for the timewalk in APD's and into simulations to understand the sources of this effect.

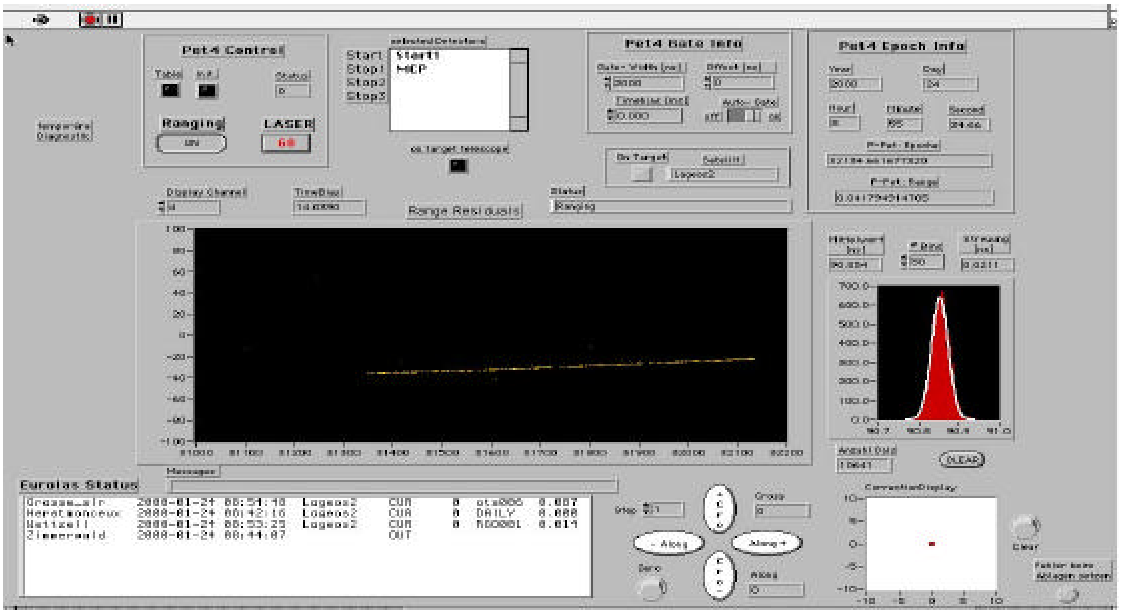

Figure 4.1-8 Front panel of the new control system at WLRS.

TIGO-SLR

The SLR system of TIGO, a Transportable Integrated Geodetic Observatory, is able to perform simultaneously two color laser ranging with an accuracy better than 1cm. The wavelength pair of 847nm/423.5nm has been chosen in order to obtain a large separation due to atmospheric dispersion.

The laser pulses are generated with a diode pumped Cr:LiSAF oscillator, amplified in a regenerative Ti:Sapphire amplifier and two Ti:Sapphire multipath amplifiers. The output energy is about 30mJ in each color at 10Hz repetition rate and pulse duration of 80ps. Figure 4.1-9 shows the laser setup in the container. Two color laser ranging should provide data to optimize atmospheric models.

Figure 4.1-9 The Ti:Sapphire laser of the TIGO SLR system

The TIGO SLR wasinstalled at Wettzell in 1998 (see Figure 4.1-10). After the first system tests of in 1998, a collocation was conducted with the WLRS. The results were presented at the 11th International Workshop on Laser Ranging, Deggendorf 1998. Since that time, major upgrades in the hardware and software have been conducted to achieve the reliability and stability which is needed to operate the system in the field. This includes: implementation of the PET4 timing system, replacement of the realtime transputer hardware, installation and adaptation of the "NEW WLRS" control software system and some improvements on the laser and the infrared detector. It is planned to have the system ready for work in summer 2000 and to again perform a collocation with WLRS. If this is successful TIGO will, in all probability, be shipped to Concepcion (Chile) at the end of this year and start its first operations at the beginning of the year 2001.

Figure 4.1-10 The SLR System of TIGO at the Wettzell site.

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4.2 NASA NETWORK

David Carter, *National Aeronautics and Space Administration*

Scott Wetzel, *Honeywell Technology Solutions, Inc.*

The NASA Network includes nine NASA operated and partner operated stations covering North America, the west coast of South America, the Pacific, and Western Australia (see Figure 4.2-1). A new station is presently being setup in South Africa and discussions are underway to add another station in Argentina. NASA SLR operations are supported by Honeywell Technical Solutions, Inc (HTSI), formally AlliedSignal Technical Services, The University of Texas, the University of Hawaii and Universidad Nacional de San Agustin.

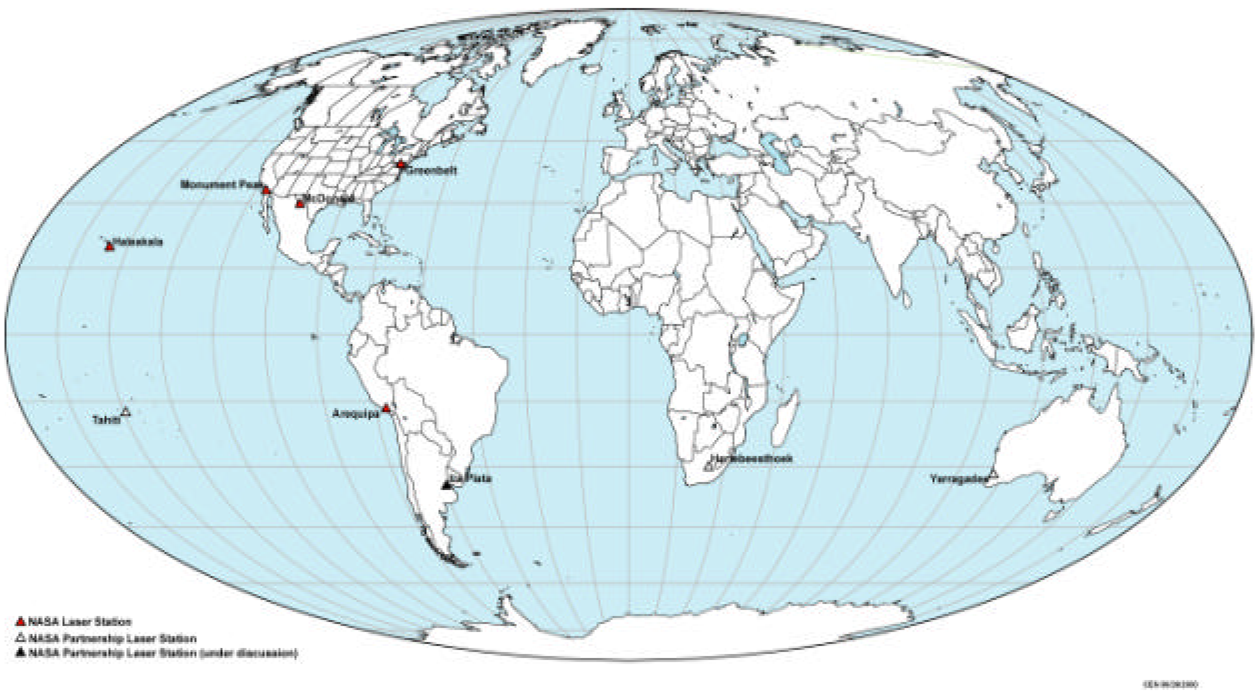

Figure 4.2-1 Map of NASA Network

Location	SLR System	Operating Agency
Monument Peak, California	MOBLAS-4	Mission Contractor (HTSI)
Greenbelt, Maryland	MOBLAS-7	Mission Contractor (HTSI)
Mount Haleakala, Maui, Hawaii	HOLLAS	University of Hawaii
Fort Davis, Texas	MLRS	University of Texas at Austin
Arequipa, Peru	TLRS-3	Universidad Nacional de San Agustin
Yarragadee, Australia	MOBLAS-5	Australian Surveying & Land Information Group
Tahiti, French Polynesia	MOBLAS-8	University of French Polynesia/CNES
Hartebeesthoek, South Africa	MOBLAS-6	National Research Foundation *
La Plata, Argentina	TLRS-4	La Plata University/CONAE **

** Setup underway; operations planned for late 2000. ** Discussions underway; operations planned for 2001.*

Table 4.2-1 NASA Satellite Laser Ranging Network

BACKGROUND INFORMATION

Satellite Laser Ranging (SLR) is a fundamental measurement technique used by the NASA Space Geodesy Program to support both national and international programs in Earth dynamics, ocean and ice surface altimetry, navigation and positioning, and technology development. The SLR technique was first developed by NASA's GSFC in the early 1960's as a tool for precision orbit determination and validation of radio tracking techniques. Since 1969, NASA has built eight trailer-based Mobile Laser Ranging Stations (MOBLAS) that could be relocated to accommodate user needs. For the past fifteen years, five of the systems have remained in operation as fixed sites. The five remaining systems were built with a flexible configuration to adapt to new technologies and improvements to increase ranging capability.

During the 1980's, NASA developed four highly compact Transportable Laser Ranging Systems (TLRS). The TLRS systems were developed in response to the need of the geophysics community to obtain SLR data at remote sites, and to support programs such as the NASA Crustal Dynamics Project, Seasat, and the Working Group of European Geoscientists for the Establishment of Networks for Earthquake Research (WEGENER) Project. The University of Texas developed the first proof of concept system, TLRS-1, in 1980.

NASA also supported the development and operation of two Observatory SLR systems at the University of Texas and University of Hawaii. Both are high performance systems with the University of Texas system having lunar ranging capability in addition to SLR.

SITE DESCRIPTIONS

Sites have been chosen to enhance global coverage of the ILRS international network. Recently NASA efforts have been aimed at redressing the relative lack of SLR stations in the Southern Hemisphere.

Table 4.2-2 describes the location of the NASA systems in 1999 and other techniques that are supported at the SLR site location.

System	1999 Location	Yrs at location	Other Collocated Techniques
MOBLAS 4	Monument Peak, California	16	GPS, Gravity
MOBLAS 5	Yarragadee, Australia	20	GPS, Doris
MOBLAS 6 *	Greenbelt, Maryland	6	VLBI, GPS, PRARE
MOBLAS 7	Greenbelt, Maryland	18	VLBI, GPS, PRARE
MOBLAS 8	Tahiti, French Polynesia	1	GPS, DORIS, PRARE, Seismometer, Tide Gauge
TLRS-3	Arequipa, Peru	9	GPS, DORIS, Seismometer
TLRS-4 *	Greenbelt, Maryland	4	VLBI, GPS, PRARE
MLRS	Fort Davis, Texas	12	VLBI, GPS, Seismometer, Lunar Laser Ranging
HOLLAS	Mount Haleakala, Maui, Hawaii	23	GPS

* System was not operational awaiting relocation

Table 4.2-2 NASA Satellite Laser Ranging Network & Other Techniques

SYSTEM DESCRIPTION

Although there are some slight differences in hardware, the system configurations of the NASA Network stations are very similar (see Table 4.2-3).

	MOBLAS	TLRS	HOLLAS	MLRS
Mount Configuration	Az/El	Az/ El	Az/ El	X-Y
Laser Type	Nd:YAG	Nd:YAG	Nd:YAG	YG402DP
Primary Wavelength	532 nm	532 nm	532 nm	532 nm
Pulse Energy	100 mJ	100 mJ	140 mJ	125 mJ
Repetition Rate	4 or 5 Hz	4 or 5 Hz	5 Hz	10 Hz
Receiver Aperture Dia.	30 in.	11 in.	16 in.	30 in.
Detector Type	MCP/PMT	MCP/PMT	MCP/PMT	MCP/PMT, SPAD
Timing Standard	GPS/Steered Rb.	Cesium	Cesium	Cesium

Table 4.2-3 System Configuration Information

MOBLAS SYSTEMS

The current MOBLAS system consists of a mobile optical mount (MOM) van and support van. All vans were originally designed to be transportable by trucks over improved roads to remote locations, but all are fixed in location. The MOM van is a semi-trailer designed to maintain all ranging and processing electronic equipment. The van measures 45 feet in length, 8 feet in overall width, and 13.3 feet in height. The interior of the van is divided into several compartments. The main compartments contain the tracking mount and optics, the laser head and power supply, and the control system and data processing instrumentation. The tracking mount and optics compartment has a retractable roof that is opened and closed by a motor-driven, chain-drive gear system. The laser has a horizontal firing angle zone of 300 degrees (360 degrees above a 20-degree elevation). The largest compartment is the instrumentation compartment which houses the data measurement system (DMS), servo control system (servo rack) portion of the tracking and mount control subsystem, interface to the antenna control console, and the meteorological display subsystem. The last compartment provides a work area and contains the air conditioning equipment.

The support van was originally provided to support MOBLAS systems when deployed to remote areas where required living quarters are not available. This van measures 40 feet in length, 8 feet in width, and 13.3 feet in height. It originally contained a sleeping area, kitchen, desk, and file cabinets for supply, maintenance, and administrative functions. The support van is now mainly used for supplies, maintenance, and administrative functions.

Figure 4.2-2 MOBLAS 7 at the GSFC in Greenbelt, Maryland

TLRS SYSTEMS

TLRS-3/4 is a highly mobile laser ranging system in that it can move from site to site and be set up in only a few days. Most of the system's electronic components are housed within a single mobile electronic equipment shelter. A second shelter is provided for personnel support. The power generator is positioned on a concrete pad nearby the electronic equipment shelter or flat bed trailer as required by site conditions.

Internally, the TLRS system is identical to the MOBLAS system in the type of laser, receiver, and timing subsystems. The major differences in the system to the MOBLAS are in the size of the trailer and mount system. Whereas the MOBLAS uses a larger 30 inch mount, the TLRS systems use an 11 inch telescope and utilize a shared transmit/receive path.

Figure 4.2-3 TLRS-4 located at the GSFC in Greenbelt, Maryland

MCDONALD LASER RANGING SYSTEM (MLRS)

The McDonald Observatory of the University of Texas is located in west Texas, near Fort Davis. After successful lunar laser ranging (LLR) experiments in March 1969, the 2.7-m Optical Observatory at McDonald became the premiere LLR station of the 1970's and early 1980's. It used a Korad ruby laser system and routinely produced LLR normal point data with an accuracy in the range 10-15 cm. After almost 16 years of continuous LLR operations at McDonald Observatory, the 2.7-m laser ranging system was de-commissioned and was superseded by a dedicated 0.76-m system. Using many of the plans and most of the equipment that was to be a part of a previously planned mobile LLR system, the McDonald Laser Ranging System (MLRS) was built. MLRS was built to range to artificial satellites as well as to the Moon. It was designed around a computer controlled 0.76-m x-y mounted Cassegrain/Coudé reflecting telescope and a short pulse, frequency doubled, 532-nm, Nd-YAG laser with appropriate computer, electronic, meteorological, and timing modules. The MLRS's epoch timing system makes all targets equivalent and crews routinely range to virtually all targets, from the closest of artificial satellites to the Moon, during a single shift.

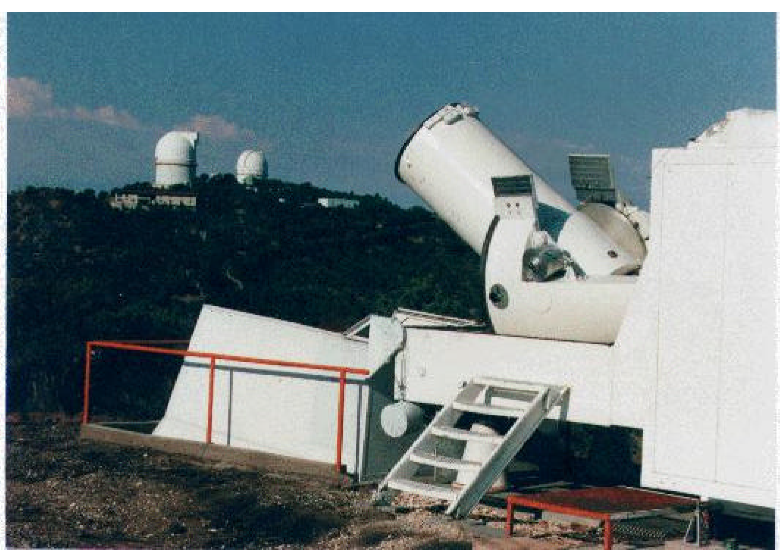

Figure 4.2-4 View of MLRS at Fort Davis, Texas

MT HALEAKALA LASER RANGING SYSTEM (H0LLAS)

HOLLAS is located is located at the 10,000 ft. summit of Mt. Haleakala on the island of Maui, Hawaii. The Observatory was developed by the University of Hawaii, Institute for Astronomy under contract from NASA GSFC. The Observatory was constructed in 1974 as a fixed Lunar Laser Ranging (LLR) station. During construction, provisions were made to accommodate SLR. LLR data was collected on a routine basis from 1985 until 1990. In 1990, LLR at the station was discontinued. Since then, activities have concentrated on SLR operations and improvements in SLR ranging capability.

The Observatory is constructed as a double domed building (see Figure 4.2-5) with the Lunar receive telescope in the 9 meter north dome. The laser transmit and satellite receive telescope is located in the 7 meter south dome. Connecting the domes is the computer control room and observer facilities. The Lunar receive telescope was mothballed in 1990, and has recently been moved to the island of O'ahu for use in a LIDAR system.

Figure 4.2-5 View of HOLLAS on Mt. Haleakala, Maui

SYSTEM UPGRADES

NASA has had a continuous program of system upgrades to improve system performance and increase automation while maintaining ranging capability to support the many programs that depend on SLR. HTSI has a small engineering group that supports network maintenance, upgrades, and new developments.

Over the last several years, aircraft detection radar, area viewing motion sensors, and cameras have been installed at each station to improved safety and security while at the same time permitting us to operate without an outside safety observer. Centralization of ranging and processing functions onto an upgraded computer platform has allowed us to standardized hardware and software, and to upgrade software and troubleshooting infrastructure. Many manual functions are being automated and the system hardware has been consolidated into a single trailer. As a result of these modifications, operating staff has now been reduced from three people to one per shift. Additional amplification has been added to the receiver chain to enhance detection on low optical margin links to GPS, GLONASS, and Etalon. Recording of meteorological functions has been automated for both SLR and IGS needs, and station timing has been upgraded by replacing the cesium tubes and FTS 8400 GPS receivers systems with the True Time GPS Steered Rubidium and the CNS Totally Accurate Clock (TAC).

TLRS 3 and 4 have also been upgraded with many of the provisions above with the intent of making the TLRS and MOBLAS systems as identical as possible and to improve the TLRS system sustainability. The TLRS systems have been equipped with the same safety features, centralized computer control system, and enhanced receiver gain feature.

Both the MOBLAS and TLRS systems can now be operated 24 hours per day, 7 days per week with a staff of 4 people.

MCDONALD LASER RANGING SYSTEM (MLRS)

At MLRS, the aircraft avoidance radar has been installed along with the other security measures to permit single operator capability. Since April 1999, MLRS has been operating 24 hours per day, 7 days per week. Improved transmitter and receiver alignment facilities also make it easier for a single operator to maintain the system. A modification to the synchronization of the Transfer/Receive (T/R) switch has improved low satellite ranging. A new CNS Totally Accurate Clock (TAC) has also been installed.

HOLLAS SYSTEM

In mid-1999, an extensive SLR hardware and software upgrading program was initiated to improve system performance and to prepare for the surge of new satellites to be launched in 2000 – 2002. Every effort was made to keep data flowing at least on critical satellites as long as possible, but in October 1999 the system ceased operations and was placed in upgrade status. The DEC PDP-11/73 and RSX OS that had been running the station since 1980 was replaced by a Pentium based system that is running LynxOS, a real-time Unix. The new MOBLAS/TLRS controller software developed by NASA is being ported to the upgraded system, and the original telescope control electronics are being replaced by a custom two axis controller being developed by Willow Systems Ltd. of Albuquerque, New Mexico. The HP-UX system, which had been used to process data, has been replaced by a PC that is running Linux OS and processing software developed by HTSI. All systems are currently in place and are undergoing final integration and debugging. The upgraded system is scheduled to resume operations in July 2000.

Using radar data for aircraft spotting from the local Federal Aviation Authority, the station is also automating safety procedures in order to implement single operator operations. As with the other NASA stations, the original timing system has been replaced with a True Time GPS Steered Rubidium and the CNS Totally Accurate Clock (TAC).

NETWORK PERFORMANCE

The NASA network systems typically demonstrate 7- 10 mm single shot range noise and 2- 3 mm normal point precision. Accuracy is probably determined by the limits of the current refraction model (Marini and Murray, 1976). The MOBLAS and TLRS systems are calibrated using a close cornercube ground target. MLRS and HOLLAS use both ground targets and internal calibration. Network timing synchronization through GPS is typically better than 100 ns. Systems operate day and night. Table 3 tabulates recent network station performance in terms of passes acquired.

During the last year the stations at Mt. Haleakala and Arequipa have been undergoing major renovation in preparation for the surge of new satellite launches starting with CHAMP planned for spring of 2000.

System	*Low Satellite*	*LAGEOS*	*High Satellites*	*Moon*
Goddard Space Flight Center	3347	833	375	0
Monument Peak	5579	1525	896	0
Mt. Haleakala (HOLLAS)	403	130	138	0
Fort Davis (MLRS)	1755	497	396	166
Arequipa	1319	209	0	0
Tahiti	827	235	38	0
Yarragadee	3709	1052	1063	0

Table 4.2-4 Passes Acquired by the NASA SLR Network in 1999

DATA OPERATIONS

The NASA Operations Center run by HTSI receives the normal points and full rate data from the NASA Network Stations by Internet. Data from the remaining ILRS stations area accessed through the CDDIS or are sent in to the Operations Center directly by the stations by FTP. Data from MOBLAS-4, MOBLAS-7, HOLLAS, and MLRS is received on an hourly basis. The data from the other stations are received daily or sub-daily at varying intervals. Normal point data is checked for format and integrity. Normal point and full rate data are transmitted to the CDDIS once per day, where it is readily available to the analysis centers and the science community. HTSI generates predictions for all ILRS satellites on a as needed basis nominally in weekly installments. These predictions are transferred to the CDDIS, the EUROLAS Data Center (EDC), and other direct methods for access by the global SLR community.

PARTNERSHIP PROGRAM

One of the key elements of the NASA SLR program is the establishment of overseas partnerships to improve the global distribution of SLR stations. Under these partnerships, NASA provides the SLR system, training, engineering support, and spare parts to maintain operations. The host country provides the site, local infrastructure, and the operating crew. NASA has successfully partnered with the Australian Surveying & Land Information Group (AUSLIG)

(MOBLAS-5) in Yarragadee, Australia and the University of French Polynesia/CNES (MOBLAS-8) in Tahiti, French Polynesia.

NASA and the South African National Research Foundation have signed a Memorandum of Understanding for the transfer of MOBLAS-6 to the Hartelbeesthoek Radio Astronomical Observatory in South Africa. The Observatory also has VLBI, GPS, DORIS, and PRARE systems. The South African station manager and senior observer were trained at NASA Goddard Space Flight Center in late 1999. Shipment of the system is scheduled for May 2000, with operations planned for mid to late 2000.

Finally, NASA is currently discussing a partnership agreement with the University of La Plata and Comisión Nacional de Actividades Espaciales CONAE in Argentina for the operation of TLRS-4. The tentative site is the University's Radio Observatory outside of La Plata.

SLR 2000

Progress on NASA's automated and eyesafe SLR2000 system continued during 1999. Funding for the SLR2000 program began in August 1997. The first year was spent developing "enabling technologies" for the system, i.e. new prototype components without which the system could not be built. This included a 2 kHz microlaser transmitter, a quadrant microchannel plate photomultiplier (QMCP/PMT), a "smart" meteorological station, and kHz rate range receiver. The second year concentrated on testing/modifying the prototype components in parallel with generating the design/specifications for other major subsystems such as the facility and dome, arcsecond precision tracking mount, telescope, and optical transceiver. During the current fiscal year, we procured the shelter and 3-meter auto-tracking dome (see Figure 4.2-6), developed the prototype tracking mount at Xybion Corporation in Florida, and fabricated the off-axis 40 cm telescope at Orbital Sciences Corporation (OSC). An isometric drawing of the tracking mount and telescope is shown in Figure 4.2-7. A stainless steel riser will serve as the interface between the tracking mount and the internal concrete monument. The optical transceiver, which is also rigidly mounted to the riser in order to maintain boresight stability with the tracking mount optical telescope, consists of the microlaser transmitter, QMCP/PMT, CCD star calibration camera, spatial and spectral filters, passive transmit/receive switch, and all interface optics with the optical telescope. Factory and field tests of the telescope and tracking mount are scheduled for late Spring/Summer of 2000. Final assembly of the total system is scheduled for completion by Fall 2001 followed by a year of field testing with replication of additional units beginning in 2003.

For more detailed information on the SLR2000 system, please visit the SLR2000 Home Page at:

http://cddisa.gsfc.nasa.gov/920_3/slr2000/slr2000.html

System photos, specifications, and all recent technical articles on the SLR2000 system presented at international conferences are available online in their entirety and are accessible via the aforementioned web site.

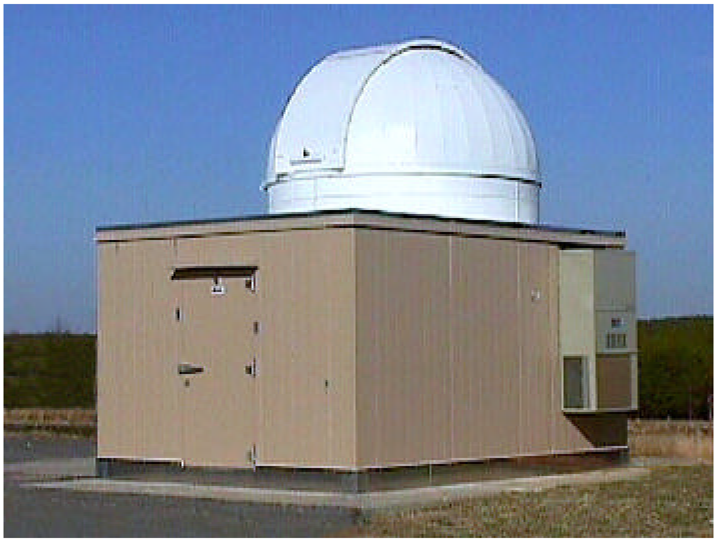

Figure 4.2-6a Exterior view of SLR2000 facility

Figure 4.2-6b Interior with Central Monument

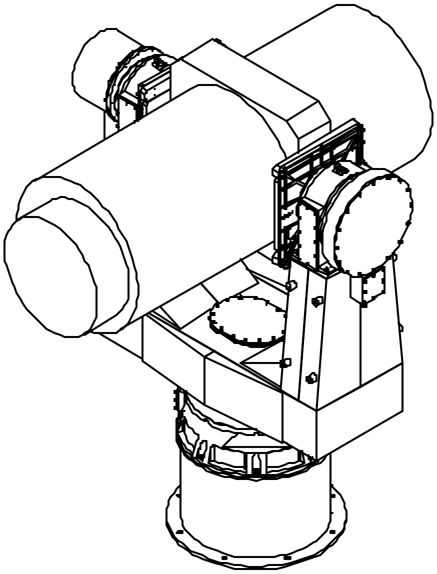

Figure 4.2-7 Isometric view of the SLR2000 tracking mount and 40 cm off-axis telescope.

4.3 WESTERN PACIFIC LASER TRACKING NETWORK (*WPLTN*)

Hiroo Kunimori, *Communications Research Laboratories*

John Luck, *Australian Surveying and Land Information Group*

4.3.1 INTRODUCTION

The WPLTN was established on 11 November 1994 during the Ninth International Workshop on Laser Ranging Instrumentation in Canberra (WPLS, 1994). Its Executive Committee initially consisted of two representatives each from Russia, China, Japan and Australia, to which have been added one each from Saudi Arabia and India. The most recent Plenary Assembly and Executive meeting were held in the week of 20-25 September 1998 during the 11th International Workshop on Laser Ranging in Deggendorf, Germany. WPLTN has had a symbiotic role in the establishment of the Keystone Project in Japan; it has provided financial support to the Russian R&D Institute for Precision Instrument Engineering (IPIE, formerly RISDE) and Mission Control Center, Moscow; it has significantly upgraded the Changchun station, China; it has provided support to restore the Saudi Arabian Laser Ranging Observatory (SALRO), Riyadh; it has organized SLR campaigns in support of the Regional Geodetic Network of the Permanent Committee on GIS Infrastructure for Asia and the Pacific; and it launched its own satellite WESTPAC on 10 July 1998. The function statement for WPLTN is given at:

http://www.auslig.gov.au/geodesy/slr/wpltn/mission.htm

and details of the WESTPAC satellite are linked through

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

Separate reports for the Russian, Chinese and Australian sub-networks are given below.

STATION STATUS AND PERFORMANCE

The Chinese stations continue to improve greatly in their productivity. The four KeyStone Project stations in Japan have improved productivity considerably since October 1999, and their quality is excellent, although it is believed that Tateyama and Miura will close at the end of June 2000. Simosato is once again very productive. Russia is building two new stations. The Australian stations continue to perform well in all aspects. SALRO is undergoing extensive repairs as resources permit. Figure 4.3.1-1 illustrates productivity at the stations in 1999. Data quality varies, as seen in the ILRS Quarterly Global Performance Report Cards.

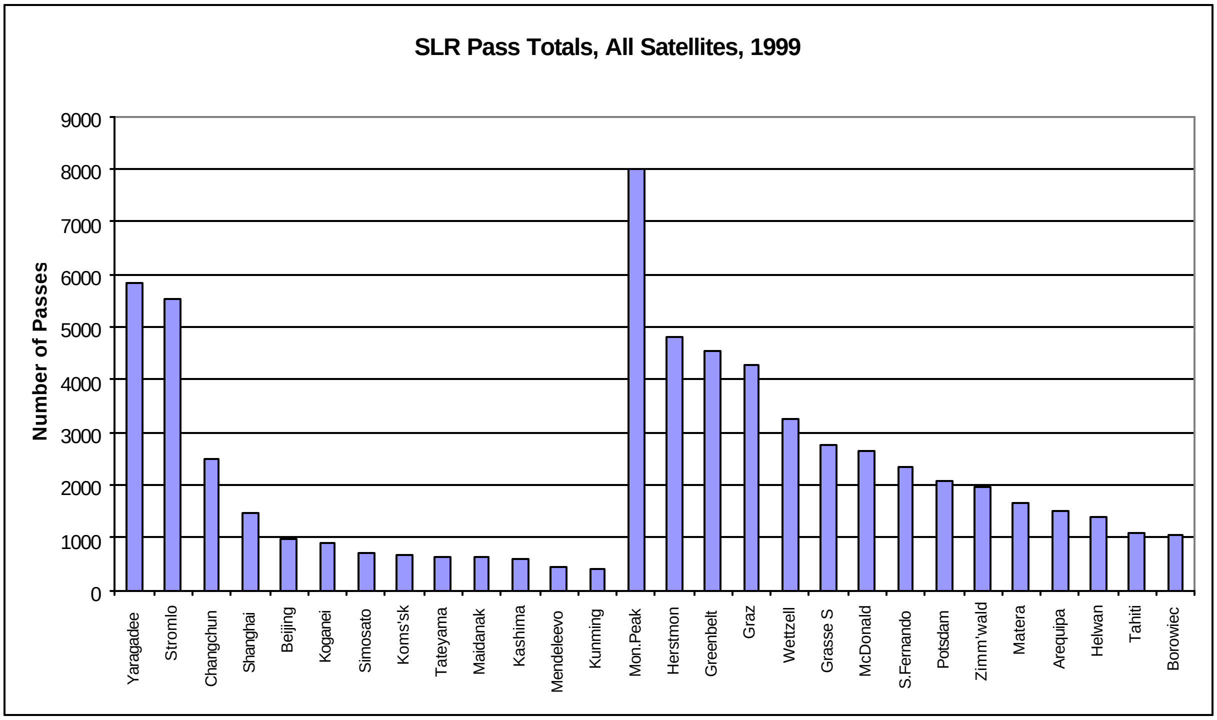

Figure 4.3.1-1 Passes in 1999, all satellites - WPLTN stations on Left, Others on Right

CAMPAIGNS

WPLTN received ILRS support for a campaign to track ETALON 1&2 during November 1999, as part of the Asia-Pacific Regional Geodetic Project APRGP'99, the latest in a series of annual projects starting in 1997 (see e.g. Luton et al, 1999). The next one is planned for October 2000. It resulted in significantly increased tracking on these targets, as shown in Table 4.3.1-1.

Period	**Average Number of Passes tracked per Week (CDDIS Reports)**			
	Etalon 1	Etalon 2	**ET1 + ET2**	Westpac
13 weeks before campaign	15.5	15.4	**30.8**	25.2
Campaign (5 weeks)	**28.6**	**37.2**	**65.8**	**31.0**
11 weeks after campaign	16.6	14.3	**30.9**	22.5

Table 4.3.1-1 ETALON Tracking rates before, during and after the November 1999 campaign.

The WESTPAC satellite continues to be tracked in quasi-campaign mode by the ILRS network. Its 1999 productivity is shown in Figure 4.3.1-2. 1418 passes were taken, on average, 27.3 passes being acquired per week

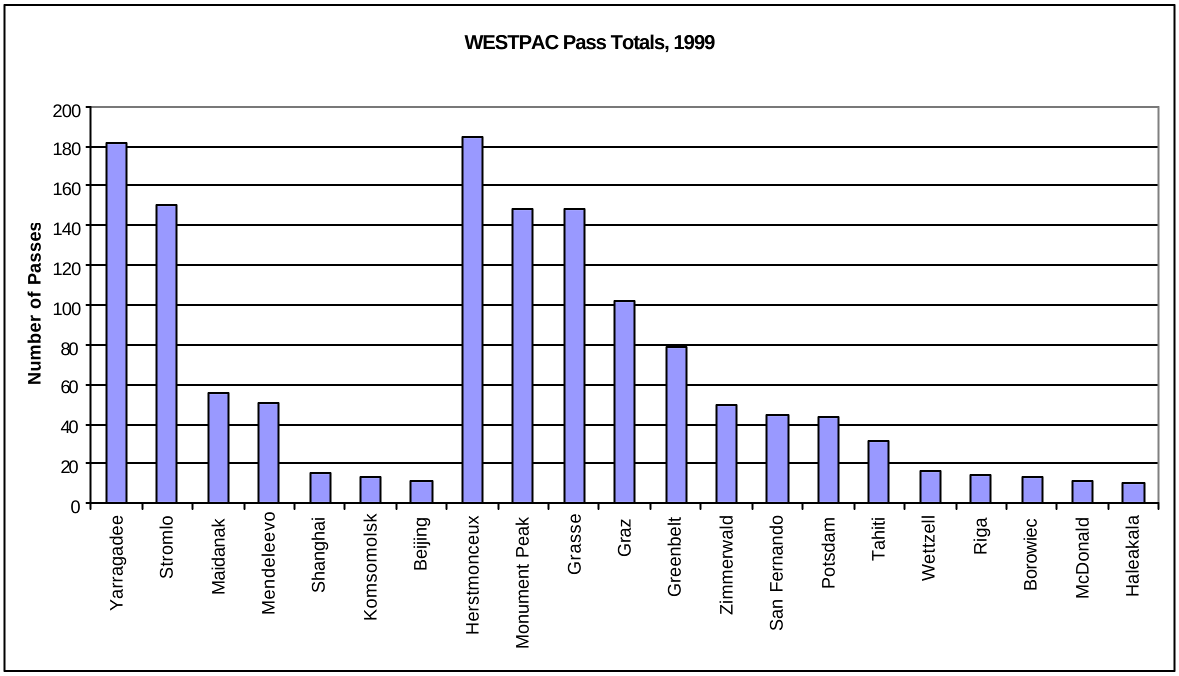

Figure 4.3.1-2 WESTPAC passes acquired during 1999, excluding week 4. From MCC weekly data summaries. Stations observing lass than 10 passes are not shown.

REFERENCES

WPLS (1994): "WPLS'94 Symposium Resolutions," *Proc Ninth International Workshop on Laser Ranging Instrumentation, Vol.3*, pp.887-8

Luton, G., Dawson, J., Govind, R. (1999): "ARPGP98 Observation Campaign Overview", *Proc. Second Workshop on Regional Geodetic Network, Ho Chi Minh City, Vietnam*, July 12th-13th 1999, pp.35-37

4.3.2 RUSSIAN NETWORK

Natalia Parkhomenko, *SRI for Precision Engineering Institute*

The Russian SLR network consists of the Komsomolsk SLR station, Mendeleevo SLR station, Maidanak SLR station, the new SLR station near Moscow, and the MCC Operational Analytic Center (MCC OAC).

KOMSOMOLSK STATION

The Komsomolsk SLR station (1868) site (see Figure 4.3.2-1) is near the Solnechny settlement, on the forest-covered plain northwest of Komsomolsk-on-Amur. The RMS number of cloudless days per year is 56 and the number of totally cloudy days per year is 113. The climate here is of a pronounced continental type. The period of most frequently cloudless weather is winter, when the air temperature is often below -40°C.

The Komsomolsk SLR station (1868) basic parameters:

- Laser pulsewidth 0.3 ns
- Detector PMT, type ФЭУ-169 (jitter 0.25 ns)
- Counter type Ч3-65 (accuracy 30 ps)
- Timing equipment A724M-01 (accuracy 200 ns)
- Reference signal source Rubidium standard frequency oscillator, type Ч1-78
- Barometer type Aneroid barometer (accuracy 0.5 mm Hg)
- Mount type equatorial
- Telescope Two apertures 0.5 m diameter each

The 1868 SLR station is capable to track satellites of any type from the ILRS list, but operates only during nighttime.

Figure 4.3.2-1. Komsomolsk SLR Station

MENDELEEVO STATION

The Mendeleevo SLR station (1870) site (see Figure 4.3.2-2) is located near Moscow, within the Institute for Time and Space Metrology (ITSM) of the Russian Agency for Standardization (GOSSTANDART of Russia). The RMS number of cloudless and totally cloudy days per year is here 47 and 156 (respectively). In 1999 our primary task was establishing the operation of a third-generation SLR system (GRAN) located not far from the Mendeleevo SLR station.

The Mendeleevo SLR station (1870) basic parameters:

- Laser pulsewidth 6 ns
- Detector PMT, type ФЭУ-165
- Counter RMS error 0.7 ns
- Timing equipment ITSM frequency standard
- Reference signal source ITSM frequency standard
- Barometer type Aneroid barometer (accuracy 0.5 mm Hg)
- Mount type Azimuth/Elevation
- Four mirrors 0.3 m diameter each

Figure 4.3.2-2 Mendeleevo SLR station

MAIDANAK STATION

The Maidanak SLR station (1864) site (see Figure 4.3.2-3) is in Uzbekistan, but is included in the Russian network under an agreement between the Russian Government and the Government of the Uzbek Republic on mutual activities in space research at the Maidanak site, dated December 22, 1997. The RMS number of cloudless and totally cloudy days is here 145 and 79, respectively. The period of mostly cloudless weather is in summer and autumn.

The Maidanak SLR station (1864) basic parameters:

- Laser pulsewidth 0.3 ns
- Detector PMT (Hamamatsu H5023)
- Counter SR620
- Timing equipment GLONASS receiver

- Reference signal source — Rubidium standard frequency oscillator, type Ч1-78
- Barometer — RTB 220B Vaisala
- Mount type — equatorial
- Telescope primary mirror diameter — 1.1 m

The 1864 SLR station is capable to track satellites of any type from the ILRS list; operates mostly during nighttime.

Figure 4.3.2-3. Maidanak SLR Station

SHELKOVO STATION

The newest Russian SLR station at Shelkovo, near Moscow (Figure 4.3.2-4), became operational in 1999. Now we are trying to obtain permission from the Government of Russia for its integration into the ILRS. Another new SLR station is under construction in the Altay region.

Basic parameters of the Shelkovo station:

- Laser pulsewidth — 0.15 ns
- Detector — PMT (Hamamatsu 5023)
- Counter — RMS error 25 ps
- Timing equipment — GLONASS receiver
- Reference signal source — Rubidium standard frequency oscillator, type Ч1-78
- Barometer type — Aneroid barometer (accuracy 0.5 mm Hg)
- Mount type — Azimuth/Elevation
- Transmit telescope — diameter 0.2 m
- Receive telescope — diameter 0.6 m

The station is capable of tracking satellites of any type from the ILRS list (low-orbit satellites and LAGEOS during daytime and nighttime).

Figure 4.3.2-4. Shelkovo (near Moscow) SLR Station

MISSION OPERATIONS AND ANALYTIC CENTER

The MCC OAC is providing ephemeris information (IRVs) for the Russian SLR network stations. The station's operation control is made through cooperation between the MCC OAC and the Institute for Precision Instrumental Engineering (IPIE); for the Mendeleevo SLR station – the ITSM. The IPIE is also providing technical support for the operation of all stations (for the Mendeleevo SLR station – in collaboration with the ITSM). The full rate data from all of the above SLR stations, after pre-processing, are sent via e-mail to the MCC OAC where an analysis is made of the data and normal points are obtained. The normal point data are then sent via e-mail to the EDC.

This procedure causes some additional delay (in comparison with other ILRS stations) in the Russian network data transfer, partly because of the five-day operation week of the MCC OAC (while the stations operate every day). Now the IPIE and MCC OAC are discussing the implementation of normal point computation at the SLR stations, and a direct transmission of normal point data from the stations to the data centers in parallel to the data transfer to MCC OAC.

The Russian SLR station equipment has been developed and implemented by the Laser Division of the Russian Institute for Space Device Engineering. On the basis of this Division, an independent enterprise has been created – the R&D Institute for Precision Instrument Engineering (IPIE), within the Russian Aerospace Agency (ROSAVIAKOSMOS). The IPIE is the leading Russian enterprise in the development and manufacturing of cube corner retroreflectors and retroreflector systems for satellite laser ranging, as well as of special laser technology satellites.

ROSAVIAKOSMOS has authorized IPIE to coordinate the operation of all Russian SLR stations, including the Russian/Uzbek 1864 station (Maidanak).

KEY POINTS OF CONTACT

Chief Coordinator of the Russian SLR network:

- Prof. Victor Shargorodsky, Chief Designer of IPIE.

Chief scientific consultant of the Russian SLR network:

- Prof. Vladimir Vasiliev (IPIE).

Executive coordinator:

- Dr. Natalia Parkhomenko (IPIE).

Representative of the Mendeleevo SLR station:

- Dr. Mark Kaufman (ITSM, GOSSTANDART of Russia).

MCC OAC Contacts:

- Dr. Vladimir Glotov
- Mr. Mikhail Zinkovsky.

See the ILRS web-site for contact information

4.3.3 CHINESE NETWORK

Yang Fumin, *Shanghai Observatory*

INTRODUCTION

The Chinese SLR network (see Figure 4.3.3-1), which consists of Shanghai, Wuhan and Changchun stations, was set up in 1989. The operation and data centers are located in the Shanghai Observatory. The Beijing station started tracking in 1992 (Wang, 1994). The Kunming station first got the returns from LAGEOS in the winter of 1998 (Zhang, 1998). The first Chinese mobile system (CTLRS-1) started ranging in 1996 (Xia, 1996). The second (CTLRS-2) will be completed in 2000 (Guo, 1998). Therefore, the Chinese SLR network will have 5 fixed stations and 2 mobile system in 2000. The performance of the stations has been greatly improved since 1997.

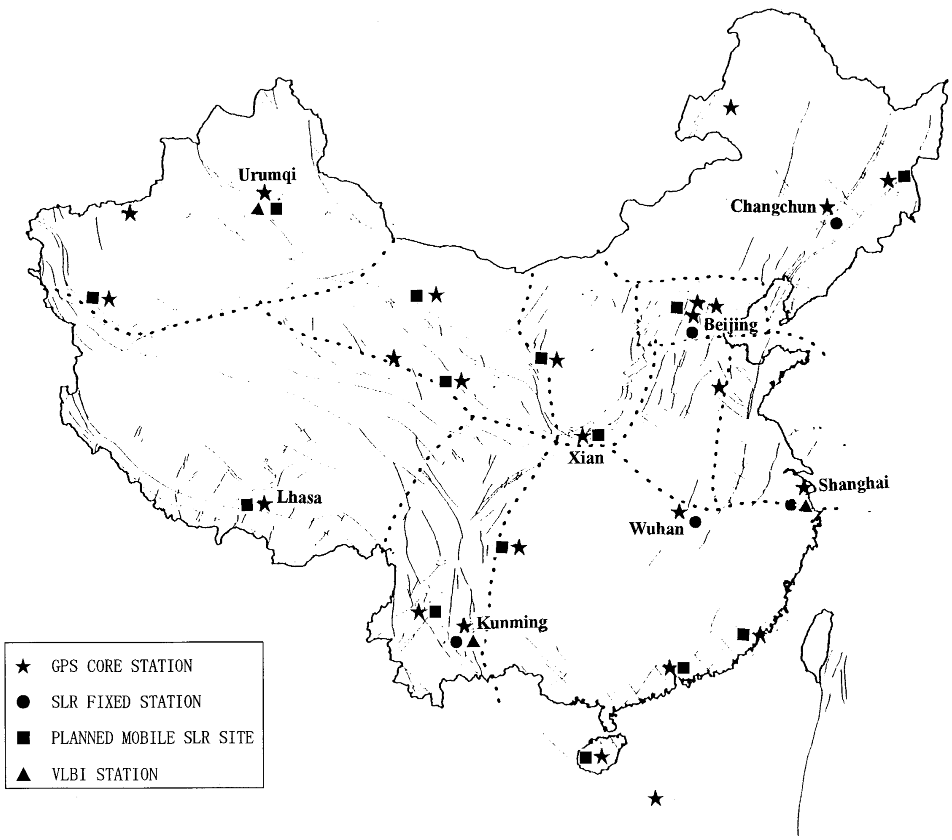

Figure 4.3.3-1 Distribution of the fixed SLR stations and the planned mobile sites

There is a cooperation agreement, supported by the Ministry of Science and Technology in China, between the National Astronomical Observatories, the Chinese Academy of Sciences and the San Juan Observatory in Argentina to host a new fixed Chinese SLR station at the San Juan Observatory by the end of 2001. The characteristics of this SLR system will be the same as the Beijing station.

PERFORMANCE OF THE CHINESE SLR STATIONS

The characteristics of the Chinese stations are listed in Table 4.3.3-1. Active-passive mode-locked Nd:YAG lasers (100mj, 200ps) are used in Changchun, Beijing and Kunming, and SFUR mode-locked Nd:YAG lasers (30-50mj, 50-100ps) are used in Shanghai, Wuhan and CTLRS-1, -2. Most of the stations are equipped the C-SPAD receivers. All stations have the HP58503A GPS time and frequency receivers. Most of the above-mentioned instruments, which were supported by the "Crustal Movement Observation Network of China (CMONOC)," have been installed since 1998.

CITY	*SHANGHAI*	*CHANGCHUN*	*BEIJING*	*WUHAN*	*KUNMING*	*CTLRS-1*	*CTLRS-2*
Station ID	7837	7237	7249	7236/7231	7820		
Aperture of Receiving Telescope	60 cm	60 cm	60 cm	60 cm	120 cm	35 cm	35 cm
Aperture of Transmitter	15 cm	15 cm	16 cm	10 cm	120 cm	10 cm	10 cm
Mount and Pointing Accuracy	Alt-AZ 5arcsec	Alt-AZ 5arcsec	Alt-AZ 5arcsec	Alt-AZ 10arcsec	Alt-AZ 1arcsec	Alt-AZ 10arcsec	Alt-AZ 10arcsec
Pulse Energy (532 nm)	30-50mj	50-100mj	50-100mj	30-50mj	100-150mj	30mj	30-50mj
Pulse Width	50-100ps	200ps	200ps	50-100ps	200ps	50-100ps	50-100ps
Repetition Rate	4-8 Hz	4-5 Hz	4-10 Hz	4-5 Hz	4-5 Hz	4-5 Hz	4-5 Hz
Type of Receiver	C-SPAD	C-SPAD	C-SPAD	C-SPAD MCP-PMT	MCP-PMT C-SPAD	MCP-PMT	C-SPAD
Time Interval Unit	HP5370B	HP5370B	HP5370B	HP5370B	SR620	SR620	SR620
Frequency Standard	HP58503A	HP58503A	HP58503A	HP58503A	HP58503A	AOA/ TTR6A	HP58503A
Ranging Precision	1-2 cm	1-2 cm	1-2 cm	2-3 cm	2-3 cm	2-3 cm	2-3 cm
Operation	Since 1983	Since 1992	Since 1994	Since 1988	Since 1998	Since 2000	Since 2000

Note: 7837 — Shanghai Observatory, Chinese Academy of Sciences
7237 — Changchun Satellite Observatory, Chinese Academy of Sciences
7249 — Chinese Academy of Surveying and Mapping (Beijing)
7236/7231 — Institute of Seismology, the State Bureau of Seismology and Institute of Geodesy and Geophysics, Chinese Academy of Sciences. 7236 is the site in the down town, 7231 is the new site in the suburbs (Wuhan)
7820 — Yunnan Observatory, Chinese Academy of Sciences (Kunming)
CTLRS-1 — Xian Institute of Surveying and Mapping
CTLRS-2 — Institute of Seismology (Wuhan)

Table 4.3.3-1 Characteristics of the Chinese SLR Stations (April 2000)

The single-shot ranging precision on LAGEOS for Shanghai, Changchun and Beijing is about 12-20 mm; for Wuhan, Kunming and the mobile systems it is 20-30 mm. Upgrades of ranging precision and system stability for all stations are under way.

The Shanghai station (see Figure 4.3.3-2) has developed a multi-satellite alternate tracking and control system and can easily change tracking objects within 20 seconds. Shanghai station also has daylight tracking capability (Yang, 1999).

Figure 4.3.3-2 Shanghai Station

The Changchun station (see Figure 4.3.3-3) has good weather and had achieved the requirements of the ILRS standards both in data quality and quantity (Zhao, 1998). The Changchun station interrupted tracking during the summer of 1999 for the installation of new encoders for both axes.

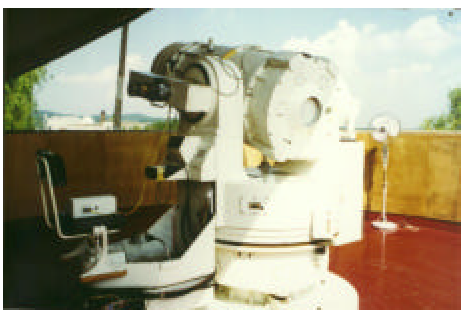

Figure 4.3.3-3 Changchun Station

Data stability and availability have improved at the Beijing station (see Figure 4.3.3-4) in 1999. The new Kunming station (see Figure 4.3.3-5) obtained about 200 passes on LAGEOS in 1999.

Figure 4.3.3-4 Beijing Station

Figure 4.3.3-5 Kunming Station

The Wuhan SLR system (see Figure 4.3.3-6) was moved to a new observation site in the southeast suburbs of Wuhan, 15 km from downtown in December of 1999. Tracking began at the new site in April 2000 and some data has been sent to CDDIS.

Figure 4.3.3-6 Wuhan Station

The system biases for most of the stations are carefully reviewed. Calibration techniques and local surveys are investigated thoroughly. The short distance targets were set up and tested in Shanghai, Changchun and Wuhan. Table 4.3.3-2 tabulates some short distance calibrations at the Shanghai Observatory. The target is in the dome in front of the telescope. The distance between the target and the reference point of the system is about 2 meters. The target setup is similar to the design of Graz station (Kirchner, 1996). Figure 4.3.3-7 lists the summary of the observations of Chinese SLR network during the period 1994-1999.

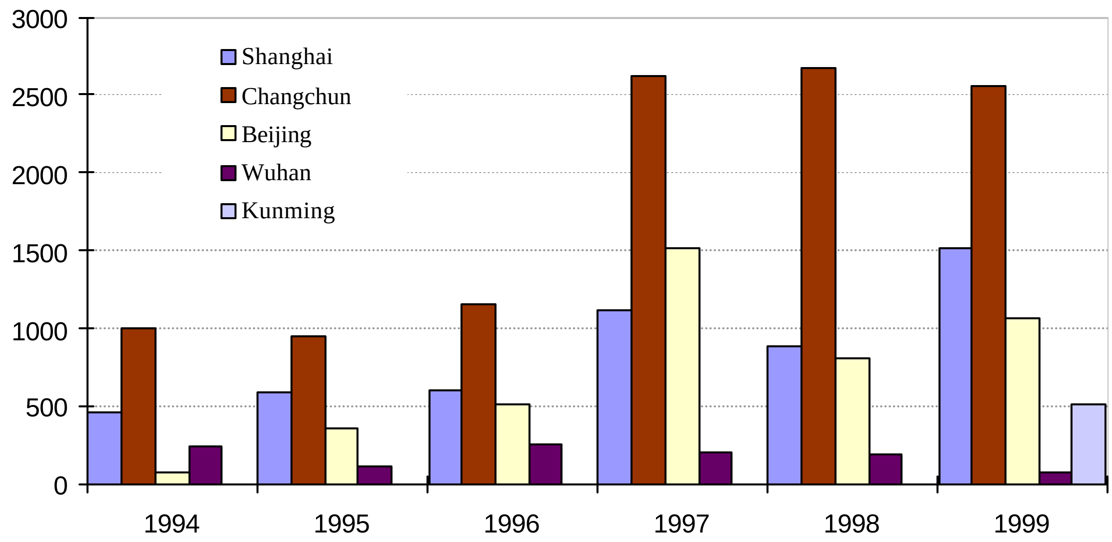

Figure 4.3.3-7 Summary of the Observations of Chinese SLR Network

Calibration (ps)	rms (mm)
80021	5.3
80026	4.7
80021	4.2
80026	5.2
80024	4.7

Table 4.3.3-2 The short distance calibration at Shanghai (April 7, 2000)

Pictures of CTLRS-1 and CTLRS-2 are shown in Figures 4.3.3-8 and -9. The SLR system under development for the San Juan Observatory is shown in Figure 4.3.3-10

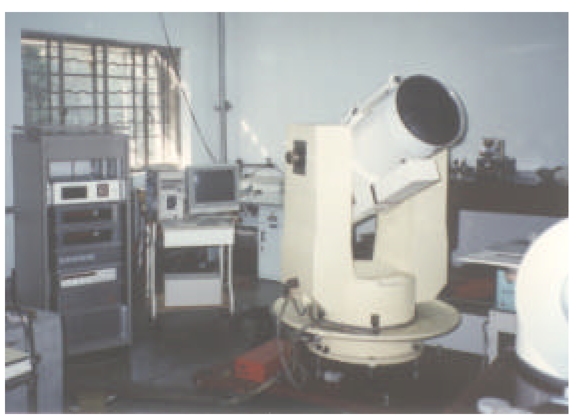

Figure 4.3.3-8 CTLRS-1


Figure 4.3.3-9 CTLRS-2

Figure 4.3.3-10 SLR Telescope for San Juan Observatory, Argentina in assembly room

THE OPERATION OF THE CHINESE SLR NETWORK

Figure 4.3.3-1 shows the location of the 5 fixed stations and the planned sites of the CMONOC project to be visited by the 2 mobile stations during the next three years.

The Operation Center, the Data Center and the Analysis Center for the Chinese SLR network have been set up at Shanghai Observatory. The Information on the Shanghai Regional Date Center and the Shanghai Associate Analysis Center can be found in Sections 6 and 7 of this Report.

ACKNOWLEDGEMENTS

We are grateful to NASA for providing support to much of the equipment for the Chinese SLR stations and to CRL Japan for providing support to a calibration package for Changchun station.

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4.3.4 AUSTRALIAN NETWORK

John Luck, *Australian Surveying and Land Information Group*

INTRODUCTION

A contract between AUSLIG and EOS to build a new SLR station based on the Keystone design, at Mount Stromlo Observatory near Canberra (Figure 4.3.4-1), was signed on 3 November 1997. The Stromlo station was commissioned on 28 October 1998. Accordingly, the Orroral Geodetic Observatory ceased SLR activity on 1 November 1998. The Orroral equipment belonging to NASA, principally the telescope, ranging computer and much of the laser, was returned in July 1999 to NASA Marshall Space Flight Center for use in its Laser Lightcraft project. The Observatory site has been restored to nature, with all buildings and facilities being demolished with the exception of the circular main building and dome which has been secured, and the survey monuments. Even the access track has been dug up. The site passed a stringent environmental assessment and was handed back to the A.C.T. Government on 13 March 2000.

Figure 4.3.4-1a Mount Stromlo SLR Station (7849): Canberra in the background, Mt. Stromlo Observatory to the right. Note two calibration piers in lower left part of the picture.

Figure 4.3.4-1b Mount Stromlo SLR Station (7849): The SLR building, highlighting the sealed dome and its window.

Figure 4.3.4-1c Mount Stromlo SLR Station (7849): Top of the main calibration pier, showing GPS antenna, target retroreflector, survey pillar plate, and protective outer tube of the support pillar.

Under a revision to the Agreement between AUSLIG and NASA for Cooperation in Space Geodesy, AUSLIG took over the operational funding for MOBLAS 5 at Yarragadee (Figure 4.3.4-2) from 1 April 1999 until 30 June 2002 through a contract with British Aerospace Australia (now BAE Systems). NASA continues to provide logistical and maintenance support. Several options are being considered for the continuance of SLR from Western Australia upon the expiry of that contract. The land adjacent to the Yarragadee station is being developed for a private space communications facility by BAE Systems for Universal Space Network, with the potential for shared power, water, optical fibre communications and transport facilities.

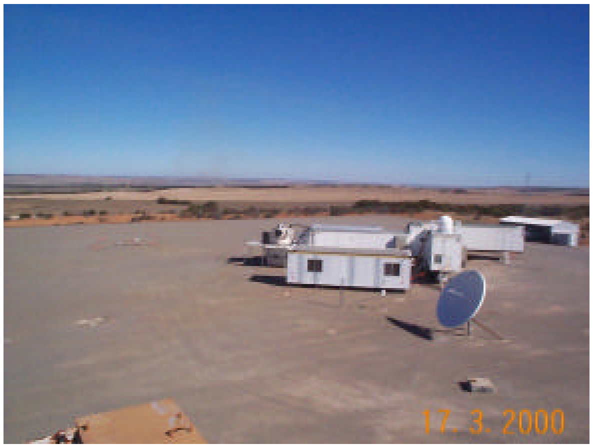

Figure 4.3.4-2: Moblas 5 (7090), Yarragadee, Western Australia

TECHNOLOGY DEVELOPMENT

This section summarizes only those developments occurring at the Mount Stromlo station (Luck, 2000). They include:

- Autonomous ranging. During parts of evenings and weekends, ranging is routinely performed automatically and unattended. It can also be controlled remotely by the Station Manager in the comfort of his own home. Productivity during autonomous sessions is still noticeably lower than when attended, but improvements to the prediction procedure and the acquisition & tracking algorithm are expected to rectify this.
- Aircraft detection by using a 1540nm laser through the ranging telescope appears to be satisfactory; no incidents have yet been recorded.
- A cloud monitor is nearing completion. It will have a 7^0 field of view and be mounted adjacent to the window in the dome, so it tracks with the telescope. This is an important adjunct to autonomous ranging.
- A high-energy laser is in use by EOS for tracking uncooperative targets. It currently delivers 1.2J at 532nm in 12ns at 20 Hz, through the normal ranging telescope. It is planned to increase the power considerably and convert to the eyesafe wavelength of 1570nm in due course. It should be useful as a “finder” laser for lunar ranging, and as a link budget probe using the OPTUS B geostationary satellites.
- A project to convert normal ranging from 532nm to 1570nm is under consideration.

LOCAL TIE SURVEYS

A cycling program of local tie surveys has been instituted by AUSLIG to support its whole range of activities in space geodesy. New software for determination of instrumental reference points has been written. Computations have been completed for the following fundamental sites and their SINEX files submitted to IGN/IERS for ITRF2000:

- Hobart VLBI and IGS GPS, observed 1995;
- Tidbinbilla VLBI and IGS GPS, observed 1995;
- Yarragadee SLR, IGS GPS, IGEX GLONASS, DORIS and SLR calibration targets, observed mainly August 1998;
- Orroral SLR, GPS and DORIS, observed November 1998 – closeout;
- Stromlo SLR, IGS GPS, IGEX GLONASS, DORIS and SLR calibration targets, observed June and December 1999.

They all include ties to the fiducial monuments at each site and local reference marks. A comprehensive report is in preparation.

The Stromlo survey of the telescope intersection of axes is complemented by the availability of four ground targets used for laser ranging. The solutions by the two independent methods agree to 1 mm.

ANALYSIS

AUSLIG's Space Geodesy Analysis Centre is an ILRS Associate Analysis Center, contributing regular solutions to IERS and to the deliberations of the Pilot Project of the Analysis WG. See section 7.1.3.6.

COLLABORATIONS

Substantial amounts of the demolished Orroral station were donated to KACST for the refurbishment of SALRO by EOS. Some returns were received from AJISAI in December 1999, giving hope that SALRO might one day be productive again.

The ex-Orroral 1-Angstrom Fabry-Perot filter was donated to Kunming, to aid their efforts to achieve daylight ranging.

REFERENCE

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4.4 LUNAR NETWORK

Peter Shelus, *University of Texas*

The present LLR network consists of the OCA station in France and the MLRS station in the USA. Both stations operate in a multiple target mode, observing many targets other than the lunar surface retroreflectors. The MLRO is a joint SLR/LLR station, presently under construction, to be installed in Matera, Italy. Operations of the MLRO should commence early in 2000. Finally, although LLR data has been gathered during previous years, by the Wettzell SLR station in Germany, station upgrades and other operational matters prevented LLR data from being obtained in 1999. It is expected that LLR data will be forthcoming from Wettzell during 2000.

OBSERVATOIRE DE LA COTE D'AZUR (OCA)

The OCA station, located in southern France on the Calern Plateau near Grasse, performed well during 1999 with no major incidents. The weather conditions were good during the spring and exceptionally good during November. This year, the OCA observing program has changed dramatically from previous years in that it is no longer a lunar only program. It is now divided among the four retroreflectors on the Moon, the two LAGEOS targets, and the several high altitude artificial satellites (GLONASS, Etalon, and GPS). Despite this large increase in the number of targets under observation, the 1999 data yield for the Moon remains excellent. In fact, both the number of returns and the number of normal points are at an all time high. The OCA station netted 653 normal points in 1999, twice that of the previous year (which had been particularly difficult). Of even more importance, the average number of returns per normal point is now 93, up from 67 last year.

Validated OCA LLR data are made available through the data centers of the ILRS and can also be retrieved from our local web-site, with a monthly update, in two formats.

The funding of the OCA station has been questioned by national authorities and investigated by a dedicated committee in June 1999. Eventually, based upon the quality of the work carried out, the scientific value of the output and the moderate annual cost (not counting salaries) the committee recommended that the operation should continue for the next four years.

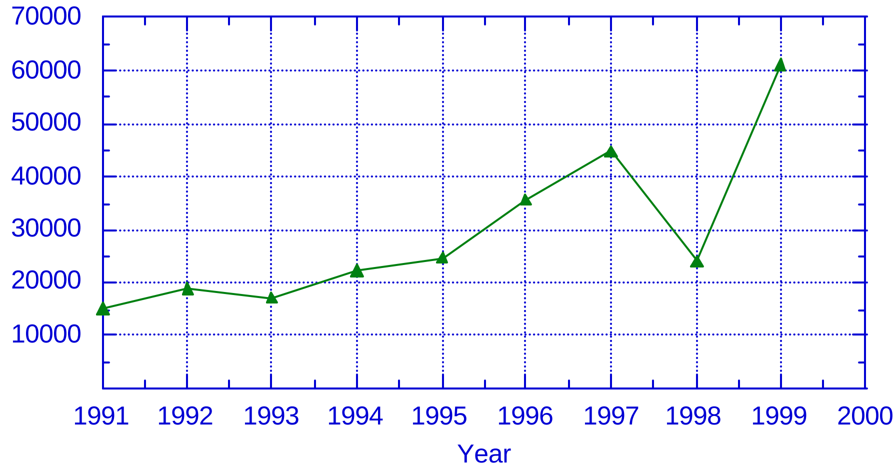

Figure 4.4-1 OCA Annual number of Returned Photons

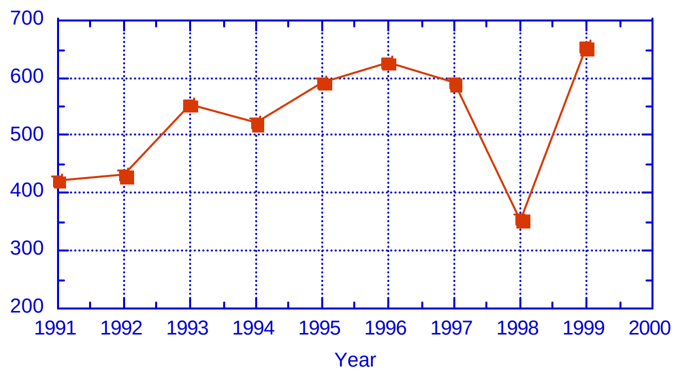

Figure 4.4-2 OCA Annual Number of Return Normal Points

The two figures illustrate the evolution of the OCA LLR data yield over the last several years. Figure 4.4-1 illustrates the number of returned photons. Figure 4.4-2 illustrates the number of normal points.

McDonald Laser Ranging Station (MLRS)

The McDonald Observatory station, MLRS, located in the mountains of west Texas, had an especially difficult year in 1999. Although LLR results had been quite good at the beginning of the year, inclement weather conditions and an unfortunate series of problems with prediction software, conspired to make the 1999 MLRS LLR data throughput, the worst since 1993 (see Figure 4.4-3).

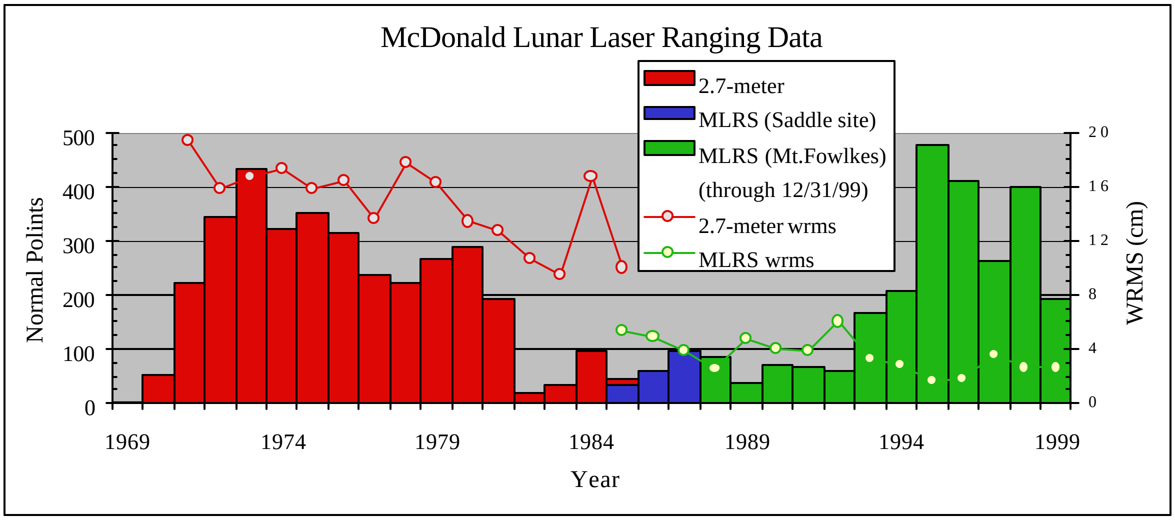

Figure 4.4-3 McDonald Observatory data quality and quantity over the life of the project.

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.

MATERA LASER RANGING OBSERVATORY (MLRO)

The Italian laser ranging station MLRO is under construction and has not ranged to the moon during 1999. However, lunar observations had been performed successfully during test firings in 1998 when the station was at the Goddard Space Flight Center's GGAO site in Greenbelt, MD. Those data files are presently under investigation. The installation of the station at the site in Matera was begun at the end of 1999 and is progressing nicely. The telescope is in the dome, the optical tables are in the clean rooms, and the remainder of the system is being assembled. It is expected that the system will be operational by end of February and be ready for routine operations, including LLR sessions, by the summer.

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