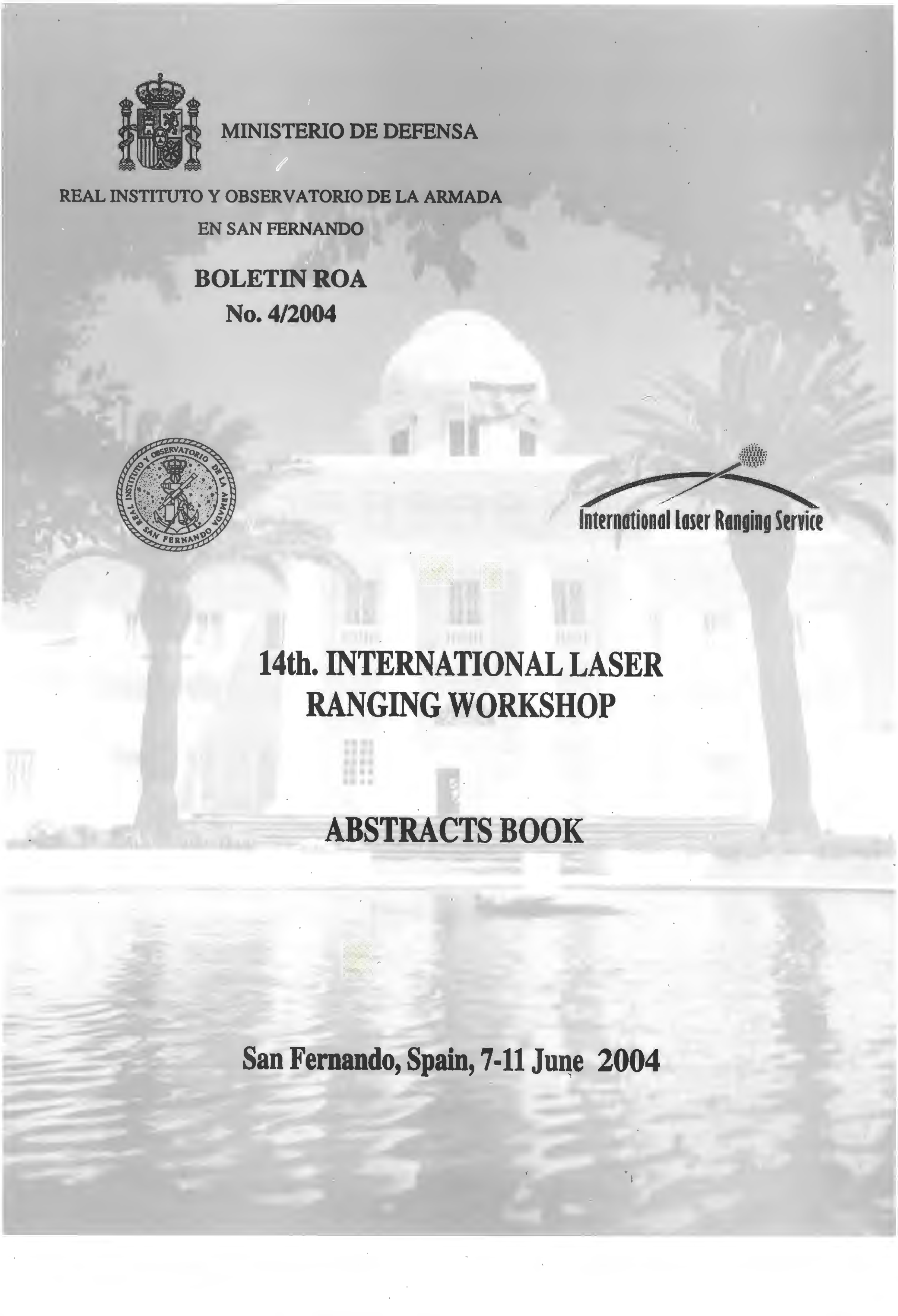

MINISTERIO DE DEFENSA

REAL INSTITUTO Y OBSERVATORIO DE LA ARMADA
EN SAN FERNANDO

BOLETIN ROA
No. 4/2004

International Laser Ranging Service

14th. INTERNATIONAL LASER RANGING WORKSHOP

ABSTRACTS BOOK

San Fernando, Spain, 7-11 June 2004

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.

FOREWORD

Geophysical and Geodetical activities at "Real Instituto y Observatorio de la Armada en San Fernando" (ROA) have a long tradition. ROA was founded in 1753 by Captain Jorge Juan after his participation in the geodetic campaign carried out in Peru, from 1735-1744, to determine the physic shape of the Earth by measuring a degree of meridian. At the end of XIXth century (1879) the first Spanish Geomagnetic station (ADIE type) was installed in the observatory. A few years later, on 1898, the first Spanish seismographic station (Milne horizontal pendulum) was installed on a pier located in the East hall of ROA main building. Three months after the "Sputnik I" was launched, a Baker-Nunn camera was set up in the Observatory, under an agreement with the Smithsonian Institution (USA). This was the first global method for ranging artificial satellites and ROA was the first Spanish and European institution incorporating to this discipline. At the end of the sixties, by means of a collaboration with the CNES-CERGA, a primitive ruby based laser station was installed at the observatory, an antecedent of the present Yag-Neodymiun based station.

From September 2003 to June 2004 ROA is celebrating its 250th anniversary by means of different activities, conferences, expositions, meetings, etc, among them, and thanks to the kindness of the "International Laser Ranging Service" (ILRS), the "14th International Laser Ranging Workshop", has been organized from 7-14 June 2004. We are honoured to host this meeting at San Fernando.

I want to thank to all participants their participation and contributions, and I wish all them a fruitful meeting and an enjoyable stay at our city.

San Fernando, May 31, 2004

Rafael Boloix Carlos-Roca
ROA Director

14TH INTERNATIONAL WORKSHOP ON LASER RANGING PROGRAM
San Fernando, Spain. June 7 - 11, 2004

Monday, June 7

9:00 - 10:00 **Welcome/Introduction**
J. Garate, J. Martin Davila, and M. Pearlman

- **ROA: 250 Years of Scientific Activities**
  R. Boloix

10:00 - 10:30 **Break**

10:30 - 12:30 **Scientific Achievements, Applications, and Future Requirements I**
E. Pavlis and J Garate

- **The Global Geodetic Observing System (GGOS) in its Initial Phase**
  H. Drewes
- **A Multi Year SLR Solution**
  H. Mueller, D. Angermann, B. Meisel
- **Processing 18.6 Years of Lageos Data**
  J.-M. Lemoine, R Biancale, G Bourda
- **SLR Contributions in the Establishment of the Terrestrial Reference Frame**
  E. Pavlis
- **Long Term Monitoring of Geophysical Parameters Using SLR**
  V. Luceri, C. Sciarretta, G. Bianco
- **Determination of EOP from Combination of SLR and VLBI Data at the Observational Level**
  N. Shuygina

Posters:

- **ROA: 250 years working in Astronomy and Geophysics (1753-2003)** (Poster)
  F.J. Gonzalez, A. Pazos
- **ESA EO Envisat and Cryosat Missions Status** (Poster)
  P. Féménias
- **NASA ICESat Mission Status** (Poster)
  B. Schutz

- **The PASAGE Project. Astrometric Positioning of Geostacionary Satellites** (Poster)
  T.L. Moratalla, C. Abad, F. Belizon, J.C. Coma, F.J. Montojo, J.L. Muiños, J. Palacio, M. Vallejo.

- **Determination of the Site Position at the SLR Tracking Station (7824) at San Fernando, Spain**
  J. Vigo-Aguiar, J. Ferrándiz, J. Gárate, J. Martín Dávila, D. García

- **FTLRS Positioning for the EU/NASA Altimeter Calibration Project GAVDOS** (Poster)
  E. Pavlis, S. Mertikas

- **Laser Ranging as a Precise Tool to Evaluate GNSS Orbital Solutions** (Poster)
  G. Appleby, T. Otsubo

- **Seasonal effects on Laser, GPS and absolute Gravimetry vertical positioning at the OCA-CERGA geodetic station, Grasse (France)** (Poster)
  J. Nicolas, J.M. Nocquet, M. Van Camp, J.P. Boy, J. Hinderer, M. Amalvict, P. Gegout, E. Calais, J.J. Walch

- **Earth Orientation Parameters from Satellite Laser Ranging** (Poster)
  E. Pavlis

- **Time Series of Satellite Laser Ranging Station Position** (Poster)
  D. Coulot, P. Berio, P. Exertier

- **The Laser Orbital Perturbation** (Poster)
  M. El-Saftawy, M. Ibrahim

- **Proposed International Institute for Space Geodesy and Earth Observation** (Poster)
  L. Combrinck

12:30 - 14:00 **Lunch**

14:00 - 16:00 **Scientific Achievements, Applications, and Future Requirements II**
B. Schutz and R. Biancale

- **Combination of Space Geodesy Techniques for Monitoring the Kinematics Of The Earth** (Poster)
  D. Coulot, R. Biancale, P. Berio, A.-M. Gontier, S. Loyer, L. Soudarin, J.-M. Lemoine, Z. Altamimi, N. Capitaine, P. Exertier and D. Gambis

- **Interannual and Annual Variations in the Geopotential Observed Using SLR**
  C. Cox, B. Chao, A. Au

- **Atmospheric Loading "Blue-Sky" Effects on SLR Station Coordinates**
  T. Otsubo, T. Kubo-oka, T. Gotoh, R. Ichikawa

- **FTLRS Support to the Gavdos Project: Tracking and Positioning**
  P. Berio, P. Exertier, F. Pierron, J. Weick, D. Coulot, O. Laurain, P. Bonnefond, FTLRS laser staff

- **Precision Orbit Determination of Low Altitude Lunar Spacecraft with Laser Systems**
  D. Smith, M. Zuber

- **Solar-System Dynamics and Tests of General Relativity with Planetary Laser Ranging**
  J. Chandler, M. Pearlman, R. Reasenberg, J. Degnan

16:00 - 16:30 **Break**

16:30 - 18:00 **Lunar Laser Ranging**
P. Shelus and J.-F. Mangin

- **MEO: The Future of the French Lunar Laser Ranging Station**
  E. Samain, G. Aridon, P. Exertier, J.F. Mangin, G.M. Lagarde, J.L. Oneto, J. Paris, F. Pierron, J.M. Torre

- **MEO Improvements for Lunokhod 1 Tracking**
  J.M. Torre, M. Furia, J.F.Mangin, E. Samain

- **Lunar Ranging from Mount Stromlo**
  B. Greene, C. Smith, Y. Gao, J. Cotter, C. Moore, J. Luck, I. Ritchie

- **Lunar Laser Ranging Science**
  J. Williams, D. Boggs, S. Turyshev, J.T. Ratcliff

- **Consolidated Laser Ranging Prediction Format: Implications for Lunar Laser Ranging**
  R. Ricklefs

- **The Apache Point Observatory Lunar Laser Ranging Operation (APOLLO)**
  T. Murphy

19:30 - **Reception at San Fernando City Hall**

Tuesday, June 8

9:00 - 10:00 **Improved and Upgraded Systems** (Poster Session)
L. Combrinck and S. Schillak

- **The Performance of Changchun Satellite Laser Ranging Station**
  L. Chengzhi, Z. You, F. Cunbo, H. Xingwei, Z. Xinghua, S. Jianyong, Z. Haitao

- **Progress for Daylight Tracking in Changchun SLR System**
  Y. Zhao

- **New Drive and Servo-Control System of Kunming SLR Station**
  Z. Xiangming, J. Chongguo, X. Yaoheng, Z. Yuncheng, L. Zhulian, W. Hanping, F. Honglin

- **San Fernando SLR Status and Future Objectives**
  J. Garate, J. Martin Davila, M. Quijano, C. Belza.

- **San Fernando Baker-Nunn Camera Transformation**
  F.J. Montojo, J. Núñez, O. Fors, M. Merino, J.L. Muiños, F.Belizón, M. Vallejo, J.M. Codina

- **Modernization of the Borowiec SLR System**
  J. Bartoszak, S. Schillak

- **Laboratory Tests and Calibration on Chronometry for the French Transportable Laser Ranging Station**
  M. Pierron, D. Feraudy, M. Faria, F. Pierron, FTLRS laser staff

- **The Performance and Observation of Mobile System TROS-1 In China**
  G. Tangyong, T. Yechun, L. Cuixia, H. Shihua, L. Xin, W. Yinzhen

- **Indian Interest On SLR**
  K. Elango, P. Soma, S.K. Shivakumar

- **The Mount Stromlo Satellite Laser Ranging (SLR) System Local Tie Connections before and after The 2003 Destructive Canberra Fires**
  J. Dawson, G. Johnston, S. Naebkhil, R. Govind

- **SGF Herstmonceux: Current Status and Future Upgrades**
  G. Appleby, P. Gibbs, D. Benham, C. Potter, R. Sherwood, V. Smith, M. Wilkinson, I. Bayer

- **Current Status of San Juan SLR Station in Argentina**
  T. Wang, F. Qu, Z. Wei, N. Liu, B. Cheng, Q. Xiang, Y. Han, W. Liu

- **Self-Mixing Optical Doppler Radial Velocity Measurements & Laser Link Budget: A Prospective Study**
  J.-L. Oneto

10:00 - 10:30 **Break and Poster Viewing**

10:30 - 12:30 **New Applications**
J. Degnan and Y. Fumin

- **Time Transfer by Laser Link T2l2**
  M. Ravet, E. Samain, R. Dalla, P. Aubry, J.M. Torre, J. Paris, J.F. Mangin, G.M. Lagarde

- **Time Transfer by Laser Pulses between Ground Stations**
  Y. Fumin, Z. Zhongping, C. Wanzhen, L. Xin, C. Juping, W. Bin

- **SLR2000C: An Autonomous Satellite Laser Ranging and Space-To-Ground Optical Communications Facility**
  J. Degnan, A. Seas, H. Donovan, T. Zagwodzki

- **Technical Concept for a European Laser Altimeter for Planetary Exploration**
  U. Schreiber, H. Michaelis, J. Oberst, I. Leike, T. Spohn

- **Laser Altimeter For Planetary Exploration**
  I. Prochazka, K. Hamal

- **Scientific Applications of Planetary Laser Altimeter Radiometry**
  M. Zuber, D. Smith

12:30 - 14:00 **Lunch**

14:00 - 16:00 **Atmospheric Correction and Multiwavelength Ranging**
C. Luceri and S. Riepl

- **Two-Wavelength Satellite Laser Ranging Experiment at Shanghai Observatory**
  Z. Zhongping, Y. Fumin, H. Jingfu, C. Wanzhen, C. Juping, L. Rendong

- **Real-Time Separation Atmospheric Tip-Tilt Signal from Lunar Surface**
  X. Yaoheng, G. Rui

- **Effects of the Atmosphere on the SLR Precision**
  J. Mulacova, K. Hamal, G. Kirchner, F. Koidl

- **Atmospheric Contribution to the Laser Ranging Jitter**
  L. Kral, I. Prochazka, G. Kirchner, F. Koidl

- **The Correction of SLR Data by the Nonlinear Dispersion of the Refraction Index of the Air**
  Y. Galkin, S. Stryukov, R. Tatevyan

- **Multiwavelength Refraction Modeling Improvements for SLR Observations**
  G. Hulley, E. Pavlis, V. Mendes, D. Pavlis

16:00 - 16:30 Break

16:30 - 18:30 **System Calibration Techniques**
U. Schreiber and F. Koidl

- **Five Target System Calibration**
  J.McK. Luck

- **New Internal Calibration Target at SGF Herstmonceux; Design and Results**
  D. Benham, P. Gibbs, V. Smith

- **MLRO Performance Characterization**
  G. Bianco, R. Sala, V. Luceri

- **Portable Pico Event Timer 2 Khz**
  K. Hamal, Ivan Prochazka

- **Tests of the Stability and Linearity of the A031et Event Timer at Graz Station**
  C. Selke, F. Koidl, G. Kirchner, L. Grunwaldt

- **Mount Model Stability**
  J.McK. Luck

- **Signal Strength Monitor for C-Spad Receiver**
  I. Prochazka, K. Hamal

20:00 - 23:00 **Trip to the Observatory, Reception**

Wednesday, June 9

9:00 - 10:30 **Engineering and Q/C Analysis I**
R. Noomen and V. Glotov

- **Numerical Noise in Satellite Laser Ranging Data Processing**
  I. Prochazka, G. Kirchner

- **Is Your Performance being Ruined by Interpolation Errors?**
  J.McK. Luck

- **Engineering Data File Processing and Distribution**
  K. Salminsh

- **Herstmonceux Time Bias System as A Possible Real-Time QC Tool**
  I. Bayer, P. Gibbs, M. Wilkinson

10:30 - 11:00 **Break**

11:00 - 12:30 **Engineering and Q/C Analysis II**
R. Noomen and V. Glotov

- **Determination of the Station Coordinates for Quality Control of the Satellite Laser Ranging Data**
  S. Schillak

- **Results of the SLR Tracking Data Quality Control During the Operational Processing**
  H. Mueller

- **MCC Analysis Procedure of the SLR Data Quality and Stations Performance**
  V.Glotov, N.Abylchatova, V.Mitrikas, M. Zinkovskiy

- **18 Years of Q/C Analysis at Delft University Of Technology**
  R. Noomen

12:30 - 14:00 **Lunch**

14:00 - 15:30 **Automation and Control Systems**
J. McGarry and W. Gurtner

- **Ray Matrix Approach for the Real Time Control of SLR2000 Optical Elements**
  J. Degnan

- **Remote Operation of GUTS-SLR**
  M. Sawabe, T. Uchimura, S. Murata, Y. Matsuoka, T. Oldham, J. Maloney

- **Consolidated Laser Ranging Prediction Format: Field Tests**
  R. Ricklefs

- **Zimmerwald Remote Control By Internet And Cellular Phone**
  W. Gurtner

16:00 - 18:00 **ILRS Governing Board Meeting**

Thursday, June 10

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

- **Laser Retroreflector Array of Geostationary Satellite, ETS-VIII**
  M. Sawabe, T. Uchimura, A. Suzuki, H. Noda

- **Design of Laser Retro-Reflector Array and Laser Ranging Experiment for Shenzhou-IV Satellite**
  Y. Fumin, C. Wanzhen, Z. Zhongping, C. Juping, W. Yuanming

- **A New Approach for Mission Design for Geodetic Satellites**
  M. Lara

- **Lageos' Asymmetric Reflectivity**
  D. Arnold, G. Appleby

- **Centre-of-Mass Correction Issues: Towards mm-Ranging Accuracy**
  T. Otsubo and G. Appleby

10:30 - 11:00 **Break**

11:00 - 12:00 **Target, Signatures and Biases II**
T. Otsubo and Appleby

- **Return Energy Estimates Derived from Normal Point and Full-Rate Laser Data**
  M. Wilkinson, G. Appleby

- **Centre-of-Mass Correction Issues: Determining Intensity Dependency at a Multi-Photon (Moblas-5) Station.**
  R. Carman, V. Noyes, T. Otsubo

- **Identifying Single Retro Tracks with a 2 Khz SLR System-Simulations and Actual Results**
  D. Arnold, G. Kirchner, F. Koidl

12:00 - 13:30 **Lunch**

13:30 - 16:00 **Advanced Systems and Techniques**
F. Pierron and H. Kunimori

- **The New Mount Stromlo SLR System**
  B. Greene, C. Smith, Y. Gao, J. Cotter, C. Moore, R. Brunswick, C. Burman

- **Overview of Guts SLR Station**
  M. Sawabe, T. Uchimura, A. Suzuki, S. Murata, Y. Matsuoka, T. Oldham, J. Maloney

- **Early Satellite Tracking Results from SLR2000**
  J. McGarry, T. Zagwodzki, J. Degnan, P. Dunn, J. Cheek, D. Patterson, H. Donovan, A. Mann, A. Mallama, R. Ricklefs

- **Graz KHz SLR System: Design, Experiences and Results**
  G. Kirchner, F. Koidl

- **The SOS-W - A Two Colour Kilohertz SLR System**
  S. Riepl, W. Schlüter, R. Dassing, K.-H. Haufe, N. Brandl, P. Lauber, A. Neidhardt

- **A Compact, Totally Passive, Multi-Pass Slab Laser Amplifier Based on Stable, Degenerate Optical Resonators**
  J. Degnan

- **Recent Achievements in Detectors for Eye Safe Laser Ranging**
  I. Prochazka, K. Hamal

- **Advanced Techniques at the EOS Space Research Centre**
  B. Greene, C. Smith, Y. Gao, J. Cotter, C. Moore, I. Ritchie, C. Burman

16:00 - 16:30 **Break**

- 18:30 **Operational Issues**
M. Pearlman and G. Kirchner

- **Data Yield of the ILRS Global Network Over The Past Decade**
  E. Pavlis

- **The ILRS Report Card and Performance Charts**
  M. Torrence, V. Husson

- **Korea's First Satellite for Satellite Laser Ranging**
  J.H. Lee, S.B. Kim, K.H. Kim, S.H. Lee, Y.J. Im, Y. Fumin, C. Wanzhen

- **EUROLAS Real Time Status Exchange**
  W. Gurtner

- **CDDIS Archive Structure Supporting Laser Ranging Data and Products** (Poster)
  C. Noll, M. Dube

- 23:00 **Banquet**

Friday, June 11

- 10:30 **ILRS General Assembly**
W. Gurtner and M. Pearlman

- 12:30 **Workshop Summary, Resolutions, Closure**.

WELCOME/INTRODUCTION

J. Garate, J. Martin Davila, and M. Pearlman

Monday, June 7

9:00 - 10:00 Conference:

- **ROA: 250 Years of Scientific Activities**
  R. Boloix

ROA: 250 YEARS OF SCIENTIFIC ACTIVITIES
Dr. Rafael Boloix, CN Director.

The origin of the Royal Naval Institute and Observatory in San Fernando, which is the oldest astronomical observatory in Spain, has its beginnings in the 18th Century. In 1751, Captain Jorge Juan of the Company of Midshipmen proposed to the Marquis de la Ensenada, the idea of building an observatory in the Castle of the Villa in Cádiz, which was the Headquarters of the Academy of Midshipmen. This was built with the intention of providing future Naval Officers with through Knowledge of Astronomy, the science that was so necessary for navigation.
From the date of 1753, the Royal Naval Observatory of Cadiz went on to earn deserved prestige in the context of European Astronomy thanks to the important development of work for personages such as Luis Godin or Vicente Tofiño and to the technical support of famous expeditions.
In 1798, the Royal Naval Observatory was transferred to the "Isla de León" in San Fernando, where it was constructed according to the plans of the Marquis of Ureña; this magnificent building has functioned until the present time. Starting in 1804, the organic dependency of the Academy of Midshipmen disappears and thus begins the scientific work of the institution into the new century, marked for well-known personages such as José Sánchez Cerquero or Cecilio Pujazón who worked in order to consolidate the function of the Observatory to its original astronomical work, added important missions to the Navy and to Spanish Science; such as the calculation of ephemeris and the publication of the Nautical Almanac, the Course of Superior Studies, the Warehouse of Chronometers and Instruments of the Navy and meteorological, seismic and magnetic observations. Nowadays the scientific activity is divided in four Departments:

DEPARTMENT OF EPHEMERIS:

It is the mission of this Department to accomplish the theoretical studies and calculations of the astronomical ephemeris following the international rules of publishing in the most adequate form to their nautical and geodetic applications.
At present, the Department publishes annually the "Efemérides Astronómicas" to be used for astronomers, the "Nautical Almanac" in original and reduced version, both dedicated to the naval and air navigator and the "Astronomical Phenomena" including information concerning to eclipses, sunrise and sunset, etc.

DEPARTMENT OF ASTRONOMY:

This Department develops their work within the field of the Astronomy of Position. Their fundamental mission is to determinate positions of celestial bodies and other magnitudes related to astronomy.
The Royal Naval Observatory participates with the Observatories of Greenwich and Copenhagen in the work of observation and investigation of the Danish Meridian Circle, whose installation on the Island of La Palma (Canary Islands) allows for the understanding of stellar catalogs of great extension and precision. The Department also uses a Meridian Circle Grubb-Parsons, the fundamental instrument of the Astronomy of Position, that, slightly modified and automated, studies the celestial sphere in coordination with the Meridian Circle of the Canary Island. The chosen place for their technical and environmental condition, is the Felix Aguilar Observatory of the University of San Juan (Argentina). Furthermore, the Astrolabe Danjon directed to work observating of the Sun after conducting important modifications and the Gautier Astrograph

incorporating a CDD camera to measure astrometric positions, has opened new possibilities of its utilization in the field of Astrometry and in the field of education.

DEPARTMENT OF TIME:

The mission of this Department is to keep of time scales in use with the highest precision and accuracy, and to disseminate them in the most convenient way for the different scientific necessities such as navigation and national industry.
The installation is composed by an ensemble of ten Cesium Beam clocks, frequency and time primary standards, and two Rubidium, secondary frequency standards. With the readings of all of them, a Time Scale named Universal Time Coordinate with the Royal Naval Observatory, (Shortly UTC (ROA)), is generated and permanently contrasted through the Time Section of Bureau des Poids et Measures (BIPM), being its differences with the Universal Time Coordinate periodically published.
The Royal Naval Observatory in San Fernando actively participates in the intercomparison of its time scale with other time laboratories in the world and it also collaborates in determining the International Atomic Time with the inclusion of all its clocks.
The Calibration Service is allocated inside this Department with the responsibility of checking time equipments to be used in the Navy. The Laboratory of this service is integrated in the national enterprise of calibration frame and it is able to issue certifications, as National Time Standard Laboratory, on the calibrations performed to the time and frequency standards of the secondary laboratories of the quality control chain in the Spanish industry.

DEPARTMENT OF GEOPHYSICS:

Concern to this Department all the subjects related with geophysics and geodesy, developing the investigation in the fields of Geomagnetism, Seismology and Satellites. It includes the Geophysical Observatory of the Navy.
For the maintenance of cooperation initiated in 1891 with the International Association of Geomagnetism, the geomagnetic installation has been moved to the Barrio de Jarana in Puerto Real, in order to avoid environmental noise.
The study of seismology has been another of the traditional fields of this Department since 1898. The equipment available includes: a Short Period seismic net, with 9 stations located in different points of the South West of Andalusia; a three components Long Period Station, located into the tunnels of the Observatory and a Broad Band seismic network, with 5 stations deployed along the South of Spain and North of Africa Region.
The Department service related to Geodesy, is called the Satellites Service, and includes the specialized observation of artificial satellites, which the Observatory incorporates from its beginnings in 1958. The service is using a 3rd generation Laser Station, installed in the dome of the main building of the Observatory, and also is working a permanent tracking GPS network. The geodetic GPS equipments belonging to the service make feasible to collaborate with different institutions in national and international campaigns.
Also belonging to this Department, is the Meteorological Station of the Observatory which is collaborating in this field with the National Meteorological Net.
This Department is responsible also for the participation in Geophysics and Geodesy campaigns, by own initiative or by invitation of other institutions. The participation in diverse Antarctic campaigns, surveys of Seismic Profiles, marine geomagnetic surveys, etc.

THE LIBRARY

The library, inseparable from the scientific chore of the Observatory and of the educational tasks of the School of Superior Studies of the Navy, has at the present time, more than, 30,000 volumes. The specialization of their bibliographic and the important collection of periodic publications transforms it into one of the most interesting scientific libraries in Spain. The old bibliographic material of the library (15^{th} to the 18^{th} Century) is composed of works by a very special group for the history of science. In addition, the Library has an important collection of cartographic material (17^{th} to 20^{th} Century) and historic documentation about the institution from 1768 to 1940.

EDUCATIONAL ACTIVITY

The School of Superior Studies in Science Mathematical Physics:
Founded in 1856, it has as its mission to give to groups of Officers of the Navy, a Physical/Mathematical Sciences Superior education which allows them, to form a faculty nucleus qualifying in Physical Sciences/Mathematics for the Higher School of learning of the Navy and in general positions, that require a special scientific preparation with a current knowledge of the evolution of the Sciences.
The Teaching is organized in two cycles: Basic and Specialization.
In order to complete the fundamental mission of the School, the Basic Cycle, with a duration of three years, is planned so that this course, increases the level so scientific preparation of Managers and Officials selected for a posterior specialization in the University and National or foreign Scientific Centres.
The Cycle of Specialization in Astronomy and Geophysics, with a duration of two years, is mainly dedicated to the preparation for the investigation and the education of the scientific personnel of the Royal Institute and Observatory of the Navy.

SCIENTIFIC ACHIEVEMENTS, APPLICATIONS, AND FUTURE REQUIREMENTS I

E. Pavlis and J. Garate

Monday, June 7

10:30 - 12:30

- **The Global Geodetic Observing System (GGOS) in its Initial Phase**
  H. Drewes

- **A Multi Year SLR Solution**
  H. Mueller, D. Angermann, B. Meisel

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  J.-M. Lemoine, R Biancale, G Bourda

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  E. Pavlis

- **Long Term Monitoring of Geophysical Parameters Using SLR**
  V. Luceri, C. Sciarretta, G. Bianco

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  N. Shuygina

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  B. Schutz

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  T.L. Moratalla, C. Abad, F. Belizon, J.C. Coma, F.J. Montojo, J.L. Muiños, J. Palacio, M. Vallejo.

- **Determination of the Site Position at the SLR Tracking Station (7824) at San Fernando, Spain**
  I. Vigo-Aguiar, J. Ferrándiz, J. Gárate, J. Martín Dávila, D. García

- **FTLRS Positioning for the EU/NASA Altimeter Calibration Project GAVDOS**
  E. Pavlis, S. Mertikas

- **Laser Ranging as a Precise Tool to Evaluate GNSS Orbital Solutions**
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- **Seasonal effects on Laser, GPS and absolute Gravimetry vertical positioning at the OCA-CERGA geodetic station, Grasse (France)**
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- **Earth Orientation Parameters from Satellite Laser Ranging**
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- **Time Series of Satellite Laser Ranging Station Position**
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THE GLOBAL GEODETIC OBSERVING SYSTEM (GGOS) IN ITS INITIAL PHASE

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The "Global Geodetic Observing System" (GGOS) of the International Association of Geodesy (IAG) was installed within the new structure of IAG during the XXIII General Assembly of the International Union of Geodesy and Geophysics (IUGG) in Sapporo, Japan, in July 2003 as its first and only project. According to its bylaws, projects of the IAG are of a broad scope and of highest interest and importance for the entire field of geodesy. They serve as the "flagship" of the Association for a long time period. At the same event in Sapporo, GGOS was endorsed by the IUGG through the Resolution No. 3.

GGOS integrates different techniques, different models and different approaches in order to achieve a better consistency, long-term reliability and understanding of geodetic, geodynamic and global change processes. It is geodesy's contribution to Earth sciences and the bridge to the other disciplines; it asserts the position of geodesy in geosciences, integrates the work of IAG and emphasizes the broad spectrum of geodetic research and application fields. GGOS provides the scientific and infrastructure basis for all global change research in Earth sciences. In the frame of GGOS, the Earth system is viewed as a whole including the solid Earth as well as the fluid components, the static as well as time-varying parameters.

GGOS is to collect, archive and ensure the accessibility of geodetic observations, results and models covering the three fundamental fields of geodesy

- *geometry and kinematics of the Earth's surface,*
- *Earth orientation and rotation, and*
- *the Earth's gravity field and its variability.*

GGOS shall identify a complete set of geodetic products in these fields and establish the requirements concerning the products' accuracy, time resolution, and consistency. It will identify eventual gaps in the products provided by the IAG services and develop strategies to close them. Intensive cooperation between existing and new IAG services shall be stimulated and the visibility of scientific research in geodesy shall be promoted and improved. By these means a maximum benefit for science shall be achieved. GGOS is geodesy's central interface to the scientific community and to society in general.

The ILRS plays an important role within GGOS. Laser observations contribute to all mentioned fields of geodesy. The International Terrestrial Reference Frame obtains its stability, in particular with respect to the geocentric orientation, from SLR observations, and long wavelength components of gravity field models are precisely determined from satellite Laser tracking. GGOS needs reliable SLR results for its successful work and requires therefore unique and consistent SLR solutions from the ILRS.

A MULTI YEAR SLR SOLUTION

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The global Satellite Ranging (SLR) network is used for the definition of the center and scale of a terrestrial reference frame, such as ITRF2000. Hence a continuous evolution and improvement of the SLR station coordinates is necessary.
Based on SLR tracking data to LAGEOS-1 in the period from January 1981 until May 2004 and LAGEOS-2 in the period from October 1992 until May 2004, a new set of SLR tracking station coordinates and velocities was computed. The basis of our computation were weekly single satellite arcs, which were accumulated to the final solution.
Since periodic signals and episodic effects influence the estimation especially of station velocities we focused on the determination of these periodical signals and breaks in the weekly time series of the station positions. Additionally we solved for low degree spherical harmonics.
The result is a homogenous set of station positions and velocities and a J2 time series. Annual signals in the station positions and breaks of linear velocities due to earthquakes or other sources were discussed.

PROCESSING 18.6 YEARS OF LAGEOS DATA

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18.6 years of good quality Lageos data are now available and can give us at last some refined value of the lunar node tide (Ω_1) as well as a better estimation of the secular drift of the dynamical flattening C_{20}.
Lageos data from 1985 until 2004, merged with Lageos2 data from 1993, were used to compute the time variations of the degree 2 coefficients of the Earth's gravitational potential. This was done with recent orbit standards, taking into account the latest developments on geopotential model from the GRACE gravity mission.
Several characteristic periods appear in the C_{20} spectrum which can be correlated mainly with tidal effects. But some inter-annual variations still remain, probably due to water mass displacement in the oceans as well as on the continents.

SLR CONTRIBUTIONS IN THE ESTABLISHMENT OF THE TERRESTRIAL REFERENCE FRAME

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The origin of the Terrestrial Reference System (TRS) is realized through the adopted coordinates of its defining set of positions and velocities at epoch, constituting the conventional Terrestrial Reference Frame (TRF). Since over two decades now, these coordinates are determined through space geodetic techniques, in terms of absolute or relative positions of the sites and their linear motions. The continuous redistribution of mass within the Earth system causes concomitant changes in the Stokes' coefficients describing the terrestrial gravity field. Seasonal changes in these coefficients have been closely correlated with mass transfer in the atmosphere, hydrosphere and the oceans. The new gravity-mapping missions, CHAMP and GRACE, and to a lesser extent the future mission GOCE, address these temporal changes from the gravimetric point of view. For the very low degree and order terms, there is also a geometric effect that manifests itself in ways that affect the origin and orientation relationship between the instantaneous and the mean reference frame. Satellite laser ranging (SLR) data to LAGEOS 1 and 2 contributed in this effort the most accurate results yet, demonstrating millimeter level accuracy for weekly averages. Other techniques, like GPS and DORIS, have also contributed and continue to improve their results with better modeling and more uniformly distributed (spatially and temporally) tracking data. We present our operational methodology and results from our latest analysis of several years of LAGEOS 1/2 and ETALON 1/2 SLR data, assess their accuracy and compare them to results from the various other techniques. A comparison of the SLR-derived trajectory of the "geocenter" with respect to the TRF, reveals a strong correlation with the recent geophysical events. The interpretation and comparison will benefit significantly from the future availability of geophysical series at higher temporal resolution and with more accurate content.

LONG TERM MONITORING OF GEOPHYSICAL PARAMETERS USING SLR

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The SLR observation dataset, similarly to the other space geodetic techniques, is a valuable source of data for measuring fundamental geophysical parameters and their temporal variations with respect to different time scales. As an example, the distinctive sensitivity of the SLR technique to global parameters as the origin and scale of the Terrestrial Reference Frame profits from the remarkable length of its observations dataset, allowing the stable and accurate retrieval of those parameters, turning into a reliable maintenance of the TRF.

The most recent and updated ASI/CGS analyses of Lageos-1 and Lageos-2 data cover two decades and provide time series of daily Earth Rotation Parameters (EOP) and Length Of Day, weekly geocenter offsets with respect to the TRF, weekly J2 estimates, station coordinates and velocities together with orbital parameters, biases, and other technique-based nuisance parameters. The complex interrelation among all the parameters allows the cross-checking and helps in detecting real geophysical signals from the parameters time series.

Some of the results coming out from the solutions will be shown, with particular emphasis to the terrestrial reference frame monitoring. Comparisons will be made with the standard IERS references.

DETERMINATION OF EOP FROM COMBINATION OF SLR AND VLBI DATA AT THE OBSERVATIONAL LEVEL

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Time series of Earth orientation parameters (EOP) are commonly obtained independently from the processing of high accuracy modern observations such as VLBI, SLR, LLR, and GPS. This paper is devoted to an attempt of determination of EOP series from the joint analysis of SLR and VLBI measurements at the observation level. We used laser ranges to geodetic satellites LAGEOS, LAGEOS 2, and Etalon 1, Etalon 2. All range measurements are taken from the Crustal Dynamics Data Informational System (CDDIS) and European Data Center (EDC). VLBI observations of distant quasars are obtained from the NEOS-A campaign. Processing of these measurements is performed in two steps. At the first stage the short arc technique with the arc length of 7 days is applied to all SLR measurements to adjust orbital parameters along with coefficients to the radiation pressure reflectance model and along track acceleration terms. All these parameters are considered to be non-stochastic. For VLBI measurements zenith component of troposphere delay and its gradients in horizontal and vertical directions are adjusted as stochastic signals on each day of observation. Both coordinates of quasars and site coordinates are considered to be accurately known and are not improved. It is very important that both SLR and VLBI observations are processed by the same program package, using the same astronomical constants and models for different kinds of measurements.
At the second stage SLR and VLBI observations are mixed to determine corrections to variables mentioned above along with all five Earth rotation parameters. Kalman filtering procedure is used to solve the system of conditional equations. Combining SLR and VLBI measurements on the short one day arc makes it possible to get standard deviations of parameters 1.5 times smaller to compare with that obtained by means of each technique separately. Applying Kalman filtering method to the longer observational time span allows us to derive EOP variations with subdiurnal periods.

ROA: 250 YEARS WORKING IN ASTROMETRY AND GEOPHYSICS (1753-2003).

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The Royal Spanish Naval Observatory is an ancient institution, founded in 1753 in Cádiz. It was the first Observatory deployed in Spain. The beginings were devoted to reseach on positional astronomy and related fields, as Celestial Mechanichs, in order to issue Nautical Almanachs, and Astronomichal Ephemeris. But soon the researching interest was extended in different ways, as Geophysics, Geodetics or Time Keeping and Dissemination. The researching in Spain on several Geophysical branches (Sismology, Geomagnetism, Meteorolgy) started here. The Observatory was also the first Spanish Institution hosting satellite tracking device: The Baker-Nun Camera delivered by the Smithsonian Institution. It is also remarkable that the observatory has got responsability for Time Keeping in Spain.
In this work, we point out the main features, in order to show a general view of the history of this important and ancient Observatory.

ESA EO ENVISAT AND CRYOSAT MISSIONS STATUS

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Envisat is the most powerful European Earth Observation satellite yet built. It has begun, since two years now, making the most complete set of observations of our planet that any satellite has ever carried out. Envisat monitors the land, Oceans, Atmosphere, Ice caps. It helps scientists to understand how changes to one, say climate, affect the others. Envisat is a key element of the European Space Agency's plans for the next decade to monitor Earth's environment.
The Envisat payload consists of a set of instruments for measuring the atmosphere and instruments for measuring the surface through the atmosphere. In particular, the Altimetry System on-board Envisat is composed of a Radar Altimeter 2 (RA-2), Microwave Radiometer (MWR), Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS), Laser Retro-Reflector (LRR).
CryoSat is a three-year Radar Altimetry Mission, scheduled for launch in 2004, to determine variations in the thickness of the Earth's continental ice sheets and marine ice cover. Its primary objective is to test the prediction of thinning arctic ice due to global warming.
CryoSat is the first satellite of ESA's Living Planet Programme to be realized in the framework of the Earth Explorer Opportunity Missions. CryoSat is a Radar Altimetry mission dedicated to the observation of the polar regions (altitude ~720 km, inclination 92 deg). Its aim is to study possible climate variability and trends by determining the variations in thickness of the Earth's continental ice sheets and marine sea ice cover.
The CryoSat mission payload is composed of a SAR/Inteferometric Radar Altimeter (SIRAL), Laser Retro-Reflector (LRR) and of a DORIS Receiver, to provide a precise orbit determination. Knowledge of the orbit is obviously essential for exploitation of the Altimeter data and the overall performance.
To ensure the highest level science return for the present Envisat and coming Cryosat missions, over the entire missions, the best orbit available is fundamental. This clearly depends on the laser tracking support. A status on the two Envisat and Cryosat Altimetry Missions is presented.

NASA ICESAT MISSION STATUS

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A new spaceborne geodetic tool was launched on ICESat in January 2003 into a 600 km altitude, near polar orbit. The NASA ICESat carries a laser altimeter, the Geoscience Laser Altimeter System, designed to generate high accuracy profiles of the polar ice sheets that enable detection of surface change. A variety of other applications have been demonstrated, which include land topography, vegetation canopy height, atmospheric and ocean. The laser altimeter channel uses a 1064 nm wavelength with a beam divergence that produces an illuminated surface spot of approximate 70 meters in diameter, whereas the atmospheric channel uses a 532 nm wavelength. With a pulse repetition rate of 40 Hz and the orbital motion, successive spots on the Earth's surface are separated by 170 m. This new geodetic tool has a precision of a few centimeters on flat surfaces and horizontal knowledge of the illuminated spot location has been shown to be approximately 15 meters, with further improvements expected. A variety of calibration/validation techniques have been applied since laser operations began in February 2003 and numerous examples of high accuracy surface profiles have been collected. This paper will summarize the current operational status and illustrate the variety of applications to Earth science.

THE PASAGE PROJECT
ASTROMETRIC POSITIONING OF GEOESTATIONARY SATELLITES

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To have precise ephemerides of geosynchronous satellites available at any time is of great importance for satellite's station keeping routines, both for planning maneuvers and for checking the results of these maneuvers.
The major goal of this project is to use earth-based astrometric observations both for obtaining precise ephemeris of geosynchronous satellites, and for orbit determination of these satellites. This use will be a new and important application of earth-based astrometry, and will require the development of the necessary techniques and algorithms for processing the observations.
Topocentric equatorial coordinates of the satellite can be obtained with one single telescope, and a sufficient number of observations can be used for orbit determination purposes. The Gautier astrographic telescope of the Real Instituto y Observatorio de la Armada (ROA), if provided with an appropriate CCD camera, will be an adequate device for doing the task. The improvement of the telescope's performances by using CCD techniques will suppose the recovery of this instrument, obsolete at present.
A better ephemeris determination can be achieved by means of astrometric observations taken from several telescopes. Observations with the Schmidt camera of Centro de Investigación de Astronomía (CIDA) in Merida (Venezuela) will be available from the beginning of the project. In the mid term, the ROA's Baker-Nun camera will also be available at Observatory Fabra II, in the Catalan Pirinee. Processing astrometric observations from these three telescopes will provide high accurate satellite positions.
The geographic positions of San Fernando, in Spain, and Mérida, in Venezuela, are ideal locations for performing astrometric observations of many different geosynchronous satellites, among which we can find the Hispasat satellites.
A redundant check on the ephemeris precision can be supported by using "two way" synchronizing techniques. Range measures can be obtained with this procedure, and at present range measurement of INTELSAT 903 are routine operations in ROA. In fact, both techniques could be mutually validated.

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DETERMINATIONS OF THE SITE POSITION AT THE SLR TRACKING STATION (7824) AT SAN FERNANDO, SPAIN.

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The ROA at San Fernando and the University of Alicante are currently engaged in a joint research project, which aims at improving the Spanish capabilities with regard to the tracking of geodetic satellites and the analysis of the data.
Special attention has been paid to the SLR tracking station at San Fernando, after instrument upgrade to meet present precision standards, as well as the requirements for computation of crustal motions and other local and regional applications in Geodesy and Geodynamics.
Improved determinations of the site position have been obtained by analyzing precise laser ranging data to LAGEOS I satellite, that together with LAGEOS II have been the mainstay in station positions and velocities for solutions of IERS in the past. The data have been obtained from NASA's CDDIS and processed using the NASA/GSFC software GEODYN/SOLVE II.
After the upgrade process that the San Fernando SLR station has been under, past determinations of the station coordinates with respect to ITRF had root-mean-square (RMS) values as large as 18 centimeters, hindering a definitive contribution to the determination of satellite orbits, and plate motions for related geodetic studies. Currently, a series of solutions has been obtained in all cases fitting data from LAGEOS I in 10-day arcs, using normal points from the global SLR tracking network. The 10-day arcs were combined to derive a set of station positions and station velocities, including the 7824 San Fernando station relative to certain other fiducial stations such as the 7110 Monument Peak as a reference to check the procedure evolution. Earth Orientation Parameters were estimated as independent values of time and polar motion at daily intervals. The IERS standards were followed except for the adoption of the EGM96 gravity field with expanded ocean tidal terms and a value of GM = 398600.4415 km^3/s^2.
The present solution UA00, was obtained applying ocean loading and measurement bias adjustments, although the latter were almost negligible (in the order of a few millimeters). RMSs for the station have been lowered, between 1.0 and 2.4 cm. for LAGEOS POD and between 2.5 and 4.9 cm. for T/P POD, reaching the standards of the best stations of the SLR network.

FTLRS POSITIONING FOR THE EU/NASA ALTIMETER CALIBRATION PROJECT GAVDOS

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The Eastern Mediterranean area is one of great interest for its intense tectonic activity as well as for its regional oceanography. Recent observations convincingly demonstrated the importance of the area for regional meteorological and climatologic changes. GPS monitors tectonics, while tide gauges record the variations in Mean Sea Level (MSL). Monitoring tide gauge locations with continuous GPS on the other hand, will remove the uncertainties introduced by local tectonics, that contaminate the observed sea level variations. Such a global tide gauge network with long historical records is already used to calibrate satellite altimeters (e.g. on TOPEX/POSEIDON, GFO, JASON-1, ENVISAT, etc.), at present, a common IOC-GLOSS-IGS effort --TIGA. Crete hosts two of the oldest tide gauges in the regional network, at Souda Bay and Heraklion. We recently completed the instrumentation of a third, state-of-the-art MSL monitoring facility in southwestern Crete, on the isle of Gavdos, the southernmost European parcel of land. Our project -GAVDOS, further expands the regional tide gauge network to the south, and contributes to TIGA and MedGLOSS. This presentation focuses on the altimeter calibration aspect of the facility, in particular, its application to the JASON-1 mission. Another component of the project is the repeated occupation of the older tide gauges at Souda Bay and Heraklion, and their tie to the new facility. The Gavdos facility is situated under a ground-track crossing point of the original T/P and present JASON-1 orbits, allowing two calibration observations per cycle. It is an ideal site if the tectonic motions are monitored precisely and continuously. The facility hosts in addition to the two tide gauges, multiple GPS receivers, a DORIS beacon for positioning and orbit control, a transponder for direct calibration and it is visited periodically by Water Vapor Radiometers and solar spectrometers. At frequent intervals we also deploy GPS-laden buoys and conduct airborne surveys with gravimeters and laser profiling lidars for a high resolution and increased accuracy of the geoid and an independent observation of the local Sea Surface Topography (SST). The French Transportable Laser Ranging System (FTLRS) completed recently a co-location campaign at the Chania, Crete base site, which has a long GPS record since 1997. The FTLRS occupation provides us with an absolute SLR-derived position in the ITRF2000 frame, the ability to compare with the GPS-derived position, and improved orbit control over the site during the campaign. This will ensure the best possible and most reliable results from the project. We will present our latest estimates of the FTLRS position and the GPS-derived velocity vectors for the site, and other relevant results.

LASER RANGING AS A PRECISE TOOL TO EVALUATE GNSS ORBITAL SOLUTIONS

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In this poster presentation we bring up to date our use of precise laser range observations to carry out independent checks on the accuracy of published orbits of a subset of the GPS and GLONASS navigational satellites. Range measurements to two GPS satellites and several of the GLONASS satellites obtained by the ILRS tracking network are compared in two ways with precise orbits computed by the IGS; by direct comparison of SLR measurements to ranges computed from the microwave orbits, and by comparison of SLR-based orbits to the microwave orbits. Our previous work, which is outlined here, has shown that in such comparisons it is necessary to understand both the potential for systematic range ambiguity induced by the laser reflector arrays and the need for accurate on-satellite positions of the array phase centres. For the GLONASS and GPS satellites these parameters are now accurately known for the several different types of array currently in orbit, and the SLR results provide an accurate assessment of the radial quality of the IGS orbits. Particularly for the GLONASS satellites, this quality has improved in recent months, but the well-known radial offset of a few cm remains between the laser measurements and the ranges computed from the radiometric orbits for the two GPS satellites. We further look forward to using similar techniques on the pilot satellites of the EU GALILEO navigational system.

SEASONAL EFFECTS ON LASER, GPS AND ABSOLUTE GRAVIMETRY VERTICAL POSITIONING AT THE OCA-CERGA GEODETIC STATION, GRASSE (FRANCE)

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The OCA station is one of the few geodetic observatories offering long time series of several space geodetic techniques and where absolute gravity measurements have been performed regularly since 1998. We present a comparison of the vertical displacement monitored by independent techniques with time series derived from SLR, GPS, and absolute gravity (AG) campaigns spanning 1998-2003. Both SLR and GPS time series show an obvious annual signal with a magnitude of 5 to 6 mm. The AG measurements also exhibit a clear annual signal of several microGal amplitude. Analysis of local baseline suggests that possible local effects do not exceed 2 mm. The comparison with atmospheric, ocean, and hydrological loading models indicates that the largest part of the signal can be explained by continental scale hydrological loading mainly due to soil moisture. The cumulative effects the different loading effects can explain the 5-6 mm observed annual variation, as well as the gravity changes.

EARTH ORIENTATION PARAMETERS FROM SATELLITE LASER RANGING

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We present the new re-analysis of Satellite Laser Ranging (SLR) data to LAGEOS 1/2 and ETALON 1/2 for the definition of the Terrestrial Reference Frame (TRF) and its crust-fixed orientation (Earth Orientation Parameters -EOP). The TRF plays an important role in the multi-technique monitoring of temporal variations in the gravitational field and its very low degree and order components. This area is becoming extremely important with the launch of recent and future geopotential mapping missions for the referencing and calibration of the data and products from these missions. Satellite laser ranging (SLR) has for a long time monitored the continuous redistribution of mass within the Earth system through concomitant changes in the Stokes coefficients of the terrestrial gravity field. Seasonal changes in these coefficients have also been closely correlated with mass transfer in the atmosphere and oceans. The hydrological cycle contributions however are the most difficult to measure accurately so far. This latest analysis of the 1993-present SLR data set from SLR data for the International Earth Rotation Service (IERS) TRF (ITRF) development includes the weekly monitoring of such compound changes in the low degree and order harmonics. Along with the static parameters of the TRF we have determined a time series of variations of its origin with respect to the center of mass of the Earth system (geocenter) and the orientation parameters (pole coordinates and length of day) of the TRF, at daily intervals. The data were obtained by the ILRS global tracking network and they were reduced using NASA Goddard's GEODYN/SOLVE II software, resulting in a final RMS error of ~8 mm – close to the data noise level. We will discuss our solution, compare it to EOP series inferred from other techniques, and examine their spectrum.

TIME SERIES OF SATELLITE LASER RANGING STATION POSITION

D. Coulot (1-2), P. Berio (2) & P. Exertier (2)
(1) IGN/LAREG - Marne-la-Vallée – France, (2) OCA/GEMINI - Grasse - France

In this paper, we study processing strategies to determine position time series by the Satellite Laser Ranging (SLR) technique. In practice, this technique limits inevitably the sampling of such time series. On the other hand, with its present sub-centimetric precision, this technique should be able to explain variations of station positions under the centimetric level. Therefore, to analyse accurately the geodynamical phenomena acting on the station movements, our aim is to obtain time series with a reasonable sampling and accuracy better than 5 mm.
Theoretical considerations on the least-squares estimation method and simulations of geometric processing show that the accuracy of the positioning solutions is limited by orbital errors and mismodelling of the crustal movements: indeed, determining a position of station valid on several days implies to suppose that phenomena like atmospheric loading can be averaged. Simulations show that it is not necessarily the case.
So, in this paper, we study a model based on wavelets for time series of station positions and present a semi-dynamical method based on Hill's theory that allows us to avoid the inaccuracy induced by orbital errors.

THE LASER ORBITAL PERTURBATION

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The laser power which can disturb the satellites orbits is presented. The disturbing function of the photon's pressure on the satellite's surface, in terms of orbital elements and the physical parameters of the laser beam, is analyzed. The effect of the Earth's atmosphere on the laser beam is also discussed. The application for different satellites is calculated.

PROPOSED INTERNATIONAL INSTITUTE FOR SPACE GEODESY AND EARTH OBSERVATION

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Initial steps are being taken to establish a world class space geodesy and earth observation facility in Southern Africa. A possible site has been identified on the Drakensberg mountain range, in Lesotho, located at an elevation of 3300 metres, just about the highest point in southern Africa. The proposed facility will be multi-disciplinary and will support all services of the IAG. Funding and management will be based on partnerships from the international community as well as local (Africa) partnerships. It is proposed that SLR, LLR, GPS and VLBI as well as complimentary geophysical instrumentation be supported. Training and capacity building will be a major component of the station's objectives. Developing a new facility will be essential for the continued presence of the major space geodetic techniques in Africa.

The proposed site, logistics and instrumentation of the new station will be discussed. A general invitation for possible partners is included.

SCIENTIFIC ACHIEVEMENTS, APPLICATIONS, AND FUTURE REQUIREMENTS II

B. Schutz and R. Biancale

Monday, June 7

14:00 - 16:00

- **Combination of Space Geodesy Techniques for Monitoring the Kinematics Of The Earth** (Poster)
  D. Coulot, R. Biancale, P. Berio, A.-M. Gontier, S. Loyer, L. Soudarin, J.-M. Lemoine, Z. Altamimi, N. Capitaine, P. Exertier and D. Gambis

- **Interannual and Annual Variations in the Geopotential Observed Using SLR**
  C. Cox, B. Chao, A. Au

- **Atmospheric Loading "Blue-Sky" Effects on SLR Station Coordinates**
  T. Otsubo, T. Kubo-oka, T. Gotoh, R. Ichikawa

- **FTLRS Support to the Gavdos Project: Tracking and Positioning**
  P. Berio, P. Exertier, F. Pierron, J. Weick, D. Coulot, O. Laurain, P. Bonnefond, FTLRS laser staff

- **Precision Orbit Determination of Low Altitude Lunar Spacecraft with Laser Systems**
  D. Smith, M. Zuber

- **Solar-System Dynamics and Tests of General Relativity with Planetary Laser Ranging**
  J. Chandler, M. Pearlman, R. Reasenberg, J. Degnan

COMBINATION OF SPACE GEODESY TECHNIQUES FOR MONITORING THE KINEMATICS OF THE EARTH

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The main goal of this paper is to study the efficiency of space technique combinations for computation of Earth's Orientation Parameters (EOPs) and Terrestrial Reference Frames (TRFs). We use four techniques: SLR, DORIS, GPS and VLBI and the parameters of interest are the following: polar motion, universal time and nutation corrections with a 6-hour sampling and station positions with a weekly sampling. We use a homogeneous computational framework for all individual computations and these computations are made over the year 2002.
In this paper, we show results for the four individual techniques used. And, in order to calibrate our method, we carry out two different combinations: a combination based directly on measurements of all techniques and a second one based on individual solutions given by each technique. The results are also compared to time series obtained by international analysis centres.

INTERANNUAL AND ANNUAL VARIATIONS IN THE GEOPOTENTIAL OBSERVED USING SLR

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Recent Satellite Laser Ranging derived long wavelength gravity time series analysis has focused to a large extent on the effects of the recent large changes in the Earth's zonals, particularily J_2, and the potential causes, or the long-term secular rates. However, it is also possible to estimate the shorter wavelength coefficients, including non-zonals, over monthly time scales, and to connect these with know geophysical signals. For example, the results of Cox and Chao [2002] showed that the recovered J_3 time series shows remarkable agreement with NCEP-derived estimates of atmospheric gravity variations. Likewise, the non-zonal degree 2 terms showed reasonable correlation with atmospheric signals, as well as climatic effects such as El Nino Southern Oscillation. While the formal uncertainty of these terms is significantly higher than that for J_2, it is clear that there is useful signal to be extracted. Consequently, the SLR time series has been reprocessed to improve the time variable gravity field recovery, with the intent of recovering complete fields through maximum spherical harmonic degree 4. Initial comparisons of the average annual signals with the GRACE monthly fields shows a promising agreement over the continents. The recovered gravity rate map also is in general agreement with expectations of post-glacial rebound, depending on the period considered. We will present recent updates on the J_2 evolution, as well the interannual and annual variations of the gravity field, complete through degree 4, and geophysical and climatic connections.

ATMOSPHERIC LOADING "BLUE-SKY" EFFECTS ON SLR STATION COORDINATES

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Earth's crust is deformed by the load of atmospheric mass. Compared to other microwave-based geodetic techniques, laser ranging observation has an advantage in accurate model of propagation delay, which must result in accurate determination of a vertical component of station coordinates. Variation of a vertical component due to atmospheric loading effect has been researched for a couple of decades, and the amount of deformation is typically 1 cm peak-to-peak or less.
The effect was already seen in GPS and VLBI data, and we found it also possible to detect the vertical variation as a function of atmospheric pressure from recent LAGEOS laser ranging data. First, we detected the pressure dependence in the post-fit residuals—the range is longer when the pressure is high. Then, using our orbit analysis software "concerto", a new adjusting parameter, height per pressure, was implemented. The parameter was estimated simultaneously with other parameters such as orbits and station coordinates, and we obtained -0.3 to -0.5 mm/hPa for the majority of laser ranging stations in the world. This result agreed well with the theoretical deformation computation and the detection studies by GPS and VLBI.
Since this optical technique is operational only under the blue or starry sky, the atmospheric pressure is higher than the average typically by 1 to 3 hPa. This means the station height is lower when the station is active. We have also found that the satellite laser ranging technique has measured the station heights lower by 0.4 to 1.3 mm than the microware techniques. In other words, it measures the size of the Earth smaller by 0.1 to 0.2 ppb. This "blue sky effect" has not been seen in the multi-technique combination research like the ITRF2000 project yet, but it could be detectable in the future.

FTLRS SUPPORT TO THE GAVDOS PROJECT : TRACKING AND POSITIONING

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In 2002, the FTLRS system performed a very successful six months campaign in Corsica for the altimeter calibration (CAL/VAL) of the JASON-1 satellite. The results have been presented on last laser workshop in Washington. After a short period of maintenance, this mobile station was again engaged in 2003 in the framework of the European GAVDOS project. The primary objective of this project is the establishment of an absolute sea level monitoring and altimeter calibration facility on the isle of GAVDOS, south of the island of Crete, Greece. The GAVDOS project will determine consistently and reliably (1) the altimeter biases and drifts for each satellite altimetric missions (TOPEX/Poseidon, JASON1, ENVISAT,...) and (2) the bias among different missions. It will also determine the mean sea level and the earth's tectonic deformation field in the region of Crete.
The FTLRS was set up in Crete (from April to October 2003 with a two month stop in July and August to avoid too warm days) in order to provide accurate data for altimeter calibrations, orbit validations and accurate positioning.
In this talk, we will present the observational balance sheet of the FTLRS Crete campaign and the positioning results obtained with a combination of LAGEOS -1, -2, STELLA, and STARLETTE observations. This solution will be compared to a GPS one.

PRECISION ORBIT DETERMINATION OF LOW ALTITUDE LUNAR SPACECRAFT WITH LASER SYSTEMS

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The need for high accuracy positioning of spacecraft in orbit about the Moon is becoming more important as many nations consider going to the Moon for both exploration and science. Particularly challenging is the control and knowledge of spacecraft position on the farside of the moon where spacecraft are unobservable from the surface of the Earth. Although, spacecraft are routinely out of view of Earth when behind any planet or body it is unique that we are never able to see and study the farside of Earth's moon from the Earth's surface. This is particularly difficult for the positioning of low altitude spacecraft that are very sensitive to even small gravity anomalies of unknown location and magnitude on the lunar farside. Of course, a variety of 2-spacraft gravity missions could reduce the problem of unknown gravity and if suitably placed could also act as a communications relay. In the long term the establishment of a farside communications spacecraft system will probably be the solution to this problem for most spacecraft. For scientific spacecraft in low altitude orbits requiring very precise spacecraft location this may not be adequate. This issue reveals itself in fig 1, a map of the gravity anomaly field of the Moon derived from Clementine and prospector tracking data.

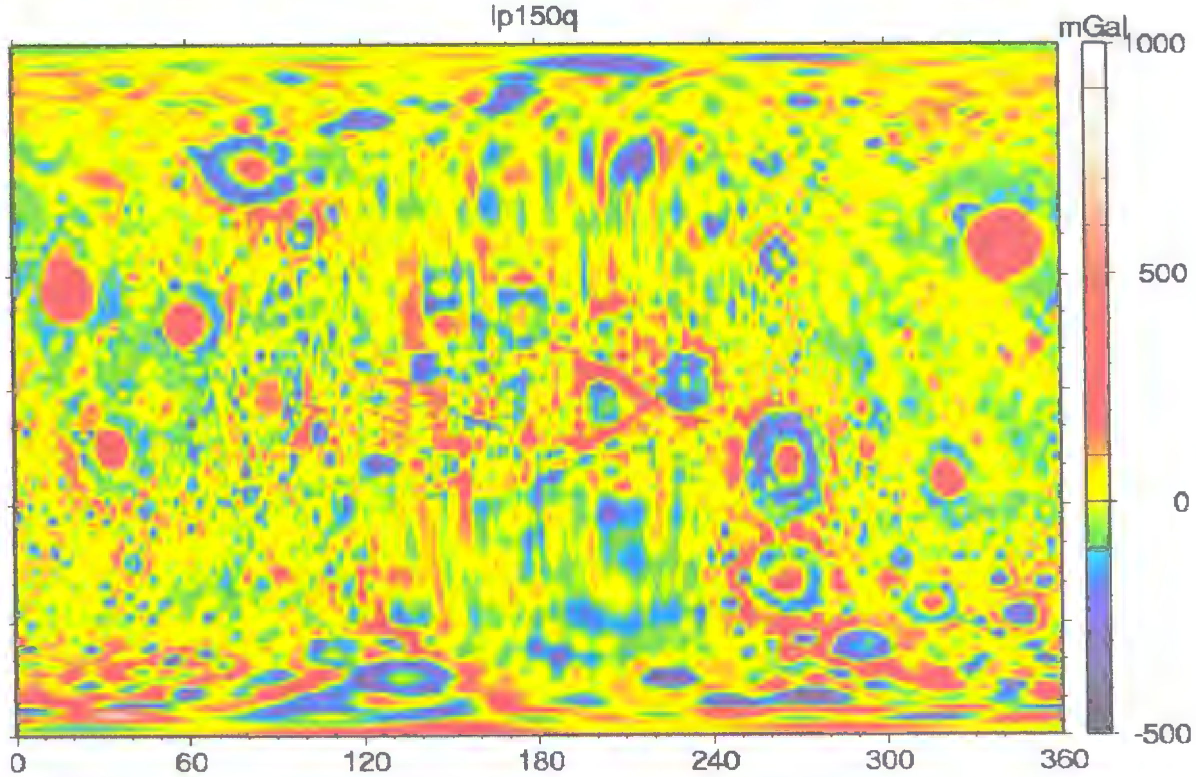

Fig 1. The gravity field of the Moon (Konopliv, 2001)

The farside of the Moon is between longitudes 90 through 270 and the figure shows clear linear striping along the ground track of the spacecraft over these longitudes. In comparison the nearside shows no such linear patterns.

One solution to improving the gravity field of the Moon is Earth-based laser tracking of a lunar satellite in conjunction with a high quality laser altimeter. Laser tracking of a lunar satellite via an optical transponder system can provide sub-centimeter level range accuracy at several kilohertz rate, equivalent to a velocity of a few tens of microns/s every 10 seconds. In addition, laser altimetry can be used to assist in the orbit determination by the introduction of altimeter cross-over measurements into the orbit determination process. This technique has been used successfully with Earth altimeter satellites over the ocean areas but has also been used successfully at Mars with the Mars Orbiter Laser Altimeter (MOLA) in the determination of the orbit of Mars Global Surveyor. But the altimeter can also be used to help determine the gravity field. Altimeter data obtained at two distinct altitudes over a region is sensitive to the higher degree and order gravity coefficients that affect the lower spacecraft more than the higher altitude spacecraft. Thus, from the analysis of the altimetry for the surface topography it is possible to extract gravity information for the region; and with global coverage it is possible to obtain global solutions suitable for precision orbit determination. Thus, for the Moon, one method of improving our knowledge of the farside gravity is to analyze a combination of nearside tracking data and nearside and farside altimetry data acquired at different orbital altitudes. With this approach we believe it is possible to obtain 10 cm radial and 5 to 10 meter horizontal accuracy orbits over the entire Moon.

SOLAR-SYSTEM DYNAMICS AND TESTS OF GENERAL RELATIVITY WITH PLANETARY LASER RANGING

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The solar system is the classical laboratory for testing the laws of gravity. Many of the most important tests of general relativity have been made using solar-system bodies. These include tests based on the advance of the perihelion of Mercury, the Shapiro time delay to the Viking Landers, and the (lack of) violation of the equivalence principle manifest by the motion of the Moon (Nordtvedt effect). Planetary Laser Ranging (PLR) promises to open up a new era of tests by yielding a major advance in the measurement of the distance between Earth and a planet. We present the results of a series of covariance studies that include the massive SAO set of solar-system data augmented by PLR data under a variety of assumptions. In particular, we consider PLR to Mars and its contribution to a time-delay test, to the measurement of the advance of the perihelia of both Earth and Mars, and to the bound on the variation with time of the strength of the gravitational interaction (G), as measured in a system of units defined by atomic processes (e.g., using atomic time). G-dot, as it is known, was discussed by Dirac as early as 1937 in connection with the Large Numbers Hypothesis, but has many modern incarnations, including those in string theory.

LUNAR LASER RANGING

P. Shelus and J.-F. Mangin

Monday, June 7
16:30 - 18:00

- **MEO: The Future of the French Lunar Laser Ranging Station**
  E. Samain, G. Aridon, P. Exertier, J.F. Mangin, G.M. Lagarde, J.L. Oneto, J. Paris, F. Pierron, J.M. Torre

- **MEO Improvements for Lunokhod 1 Tracking**
  J.M. Torre, M. Furia, J.F.Mangin, E. Samain

- **Lunar Ranging from Mount Stromlo**
  B. Greene, C. Smith, Y. Gao, J. Cotter, C. Moore, J. Luck, I. Ritchie

- **Lunar Laser Ranging Science**
  J. Williams, D. Boggs, S. Turyshev, J.T. Ratcliff

- **Consolidated Laser Ranging Prediction Format: Implications for Lunar Laser Ranging**
  R. Ricklefs

- **The Apache Point Observatory Lunar Laser Ranging Operation (APOLLO)**
  T. Murphy

MEO : THE FUTURE OF THE FRENCH LUNAR LASER RANGING STATION

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The French laser ranging capacity, is based on 3 laser tracking stations:

Lunar Laser Ranging (LLR) for the Moon and high altitude satellites,
Satellite Laser Ranging (SLR) for low altitude satellites,
Transportable Laser Ranging System (FTLRS) for mobile campaigns.

Since the beginning of the year 2004 a new organization has been set up that will permit to initiate, in addition to the actual program on the Moon and satellites, a new research and development activity. In this framework, it has been decided to centralize our work on both LLR and FTLRS stations and to stop SLR definitively.
Because the LLR activity becomes more versatile, LLR station is now renamed MeO (Metrology and Optics). Data acquisitions on low Earth altitude satellites, that were performed until now by the SLR station, will be done by MeO exclusively.
The new research and development activity on laser ranging will include: new kind of laser modulation, filtering, detection, multi-colors, Doppler, Adaptative optics… and also research on laser ranging in the solar system (ASTROD, TIPO).
In order to achieve all these objectives, many developments are in preparation :

Telescope : high speed motorisation, high accuracy pointing
Dome : new guiding device
Building : offices, focus laboratory
Optics : optical benches for experimental research, optical path
Operational telemetry : lasers, high speed laser commutation, photo-detection
Softwares

The progress report of this program will be presented.

MEO IMPROVEMENTS FOR LUNOKHOD 1 TRACKING

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Five targets have been disposed on the Moon. Three by American missions (Apollo XI, XIV, XV) and two by Soviet missions (LUNA17, LUNA21). The targets of LUNA missions are installed on mobile vehicles (Lunokhod 1 and 2). One of these targets, disposed by LUNA17 mission, is not used at the present time. The goal of MeO improvements is to be in the best conditions to try to acquire data on Lunokhod 1 retro reflector.
We present the target constitution (quality and efficiency), the previous campaigns and the improvements of MeO station based on this particular target (detector, laser and software).
In conclusion, we present the results of the last few months campaign.

LUNAR RANGING FROM MOUNT STROMLO

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The Mount Stromlo SLR system is co-located with the EOS space Research Centre [SRC] which has extremely powerful laser tracking capabilities.
The SLR normally operates with 0.5W of laser power, but in recent months the system has been coupled to an available 50W laser and LLR sessions have been programmed from late May by EOS, using EOS research funds.
The LLR link should be acceptable with 50W laser power, since the SLR telescope has 100cm high-quality optics and 5 microradian absolute pointing. The accuracy of the experimental configuration will be at the 10 cm level, but this can be later upgraded once target links have been established.
The initial objective of this experiment is to determine [update] the relative responsiveness of various lunar targets, and establish operational parameters for a long-term lunar capability using millimetre-accurate systems.
The operational configuration of this system, and any initial results will be presented.

LUNAR LASER RANGING SCIENCE

James G. Williams, Dale Boggs, Slava Turyshev, and J. Todd Ratcliff
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Analysis of Lunar Laser Ranging (LLR) data provides science results: gravitational physics and ephemeris information from the orbit, lunar science from rotation and solid-body tides, and Earth science.

Science from the orbit. Sensitive tests of gravitational physics include the equivalence principle, limits on the time variation of the gravitational constant G, and geodetic precession. The equivalence principle test is used for an accurate determination of the Parametrized Post-Newtonian Parameter beta. Lunar ephemerides are a product of the LLR analysis used by current and future spacecraft missions. The analysis is sensitive to astronomical parameters such as orbit, masses and obliquity. The dissipation-caused acceleration in orbital longitude is -25.7 $''/\mathrm{cent}^2$, dominated by tides on Earth with a 1% lunar contribution.

Lunar science. Lunar rotational variation has sensitivity to interior structure, physical properties, and energy dissipation. The second-degree lunar Love numbers are detected; k_2 has an accuracy of 11%. Lunar tidal dissipation is strong and its Q has a weak dependence on tidal frequency. A fluid core of about 20% the moon's radius is indicated by the dissipation data. Evidence for the oblateness of the lunar fluid-core/solid-mantle boundary is getting stronger. This would be independent evidence for a fluid lunar core. Moon-centered coordinates of four retroreflectors are determined.

Earth science. Station positions and motion, Earth rotation variations, and precession are determined from analyses.

Future. Extending the data span and improving range accuracy will yield improved and new scientific results. Adding either new retroreflectors or precise active transponders on the Moon would improve the accuracy of the science results.

CONSOLIDATED LASER RANGING PREDICTION FORMAT : IMPLICATIONS FOR LUNAR LASER RANGING

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The new ILRS consolidated ranging target prediction format has been developed by the ILRS Prediction Formats Study Group to provide a single format to encompass traditional artificial satellite and lunar ranging targets as well as proposed transponder targets on or around the moon and other planets. The primary benefit will be to allow any ranging station convenient access to ranging any of these target categories. This has the potential of expanding the effectiveness of new and existing laser ranging stations and removing one obstacle to increased lunar ranging capaibilies in the ILRS network.

THE APACHE POINT OBSERVATORY LUNAR LASER RANGING OPERATION (APOLLO)

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The Apache Point Observatory Lunar Laser-ranging Operation (APOLLO) is nearing completion, with anticipated first light in the fall of 2004. Using a 3.5-meter aperture telescope at a 2,880-m site will result in multi-photon returns from the lunar reflectors. An avalanche photodiode array will allow separate time-tagging of each received photon within the pulse. We have explored the time response of our detectors in great detail, and conclude that the total system error will certainly be dominated by the orientation and finite size of the lunar reflector arrays. Even if our photon rate is five times less than anticipated, we will still receive about one photon per pulse, on average, or 20 photons per second at a 20 Hz pulse rate. At this rate, we will be able to achieve millimeter RMS range precision on the timescale of one minute. The high photon rate additionally allows us to study sources of systematic error in detail, and will also facilitate feedback for optimization of the system throughput.

IMPROVED AND UPGRADED SYSTEMS

(Poster Session)

L. Combrinck and S. Schillak

Tuesday, June 8

09:00 - 10:00

- **The Performance of Changchun Satellite Laser Ranging Station**
  L. Chengzhi, Z. You, F. Cunbo, H. Xingwei, Z. Xinghua, S. Jianyong, Z. Haitao

- **Progress for Daylight Tracking in Changchun SLR System**
  Y. Zhao
- **New Drive and Servo-Control System of Kunming SLR Station**
  Z. Xiangming, J. Chongguo, X. Yaoheng, Z. Yuncheng, L. Zhulian, W. Hanping, F. Honglin

- **San Fernando SLR Status and Future Objectives**
  J. Garate, J. Martin Davila, M. Quijano, C. Belza.

- **San Fernando Baker-Nunn Camera Transformation**
  F.J. Montojo, J. Núñez, O. Fors, M. Merino, J.L. Muiños, F.Belizón, M. Vallejo, J.M. Codina

- **Modernization of the Borowiec SLR System**
  J. Bartoszak, S. Schillak

- **Laboratory Tests and Calibration on Chronometry for the French Transportable Laser Ranging Station**
  M. Pierron, D. Feraudy, M. Furia, F. Pierron, FTLRS laser staff

- **The Performance and Observation of Mobile System TROS-1 In China**
  G. Tangyong, T. Yechun, L. Cuixia, H. Shihua, L. Xin, W. Yinzhen

- **Indian Interest On SLR**
  K. Elango, P. Soma, S.K. Shivakumar

- **The Mount Stromlo Satellite Laser Ranging (SLR) System Local Tie Connections before and after The 2003 Destructive Canberra Fires**
  J. Dawson, G. Johnston, S. Naebkhil, R. Govind

- **SGF Herstmonceux: Current Status and Future Upgrades**
  G. Appleby, P. Gibbs, D. Benham, C. Potter, R. Sherwood, V. Smith, M. Wilkinson, I. Bayer

- **Current Status of San Juan SLR Station in Argentina**
  T. Wang, F. Qu, Z. Wei, N. Liu, B. Cheng, Q. Xiang, Y. Han, W. Liu

- **Self-Mixing Optical Doppler Radial Velocity Measurements & Laser Link Budget: A Prospective Study**
  J.-L. Oneto

THE PERFORMANCE OF CHANGCHUN SATELLITE LASER RANGING STATION

Liu Chengzhi, Zhao You, Fan Cunbo, Han Xingwei, Zhang Xinghua, Shi Jianyong, Zhang Haitao.
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This paper introduces the performance and observation summary of the SLR system at Changcun Observatory, Chinese Academy of Sciences. The performance of the SLR system has been greatly improved since August 1997. The single shot precision reaches 1-2cm from 5-7cm and the normal point precision reaches 4-7mm. The long term stability is better than 1cm. The amount of observation has been increased from about 1000 passes to around 5000 passes. The whole performance of Changcun SLR system has accessed to the advanced level among the worldwide SLR stations.

Technical Upgrade

(*) Calibration System. The PCS is an independent accurate timing device, which is used as a diagnostic tool for SLR stations. It works parallelly with the SLR operational system, only needs start and stop signals provided from the operational system, and there is no any interference on the original system. The structure scheme of the PCS is presented in figure 1. The SR620 interval counter and PCE(control circuit of PCS) are kept in a temperature control metal box (40°) so as to keep their stability and reliability. We can easily find the problems if there are any in our operational SLR system via comparison of the results between PCS system and the operational one [2].

The characteristics of the PCS are as follows:

SR620 Time Internal Counter: resolution 4ps,time jitter<50 ps,rms

HP58503A GPS Receiver:epoch accuracy 0.1μs frequency stability 5×10^{-12}/day

PCE (PCS control part) resolution 0.1μs

Meteorological Sensor Para Scientific barometric resolution 0.01mbar, accuracy 0.1mbar/year

(*) Receiving System:The C-SPAD with time walk compensation circuit and the temperature control shell was adopted as photo-electronic detector instead of the old photo-multiplier tube. The features of C-SPAD are high quantum efficiency, small time walk, automatic compensation and low working voltage. So it decreases the system ranging bias caused by the variation of return signal amplitude and has larger dynamic range. It has been shown in the test that the timing error of the C-SPAD is 43ps, so better observation accuracy can be obtained[3][4].

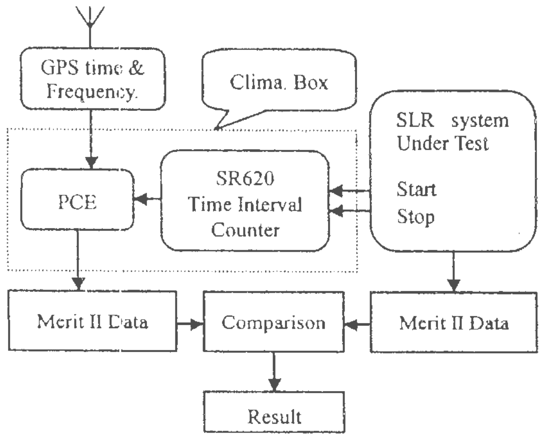

Figure1 PCS Structure Scheme

(*) Timing System: HP58503A GPS time frequency receiver supplies 10MHz signal and the second pulse that is synchronized to GPS time to the control system and receiving system. The tracking software is improved to synchronize time automatically every pass so as to reduce time walk and enhance the stability of time system.
(*) Servo System and Encoder Electronics. A new servo system for the mount was built. As some microprocessors substitute for the old relays, the stability becomes better. The servo system adopts IGBT, its tracking ability for low orbit satellite boost up, and the tracking error for high orbit satellite is apparently diminished [5]. The new encoder electronics uses a circuit with 23 bit (0.155"resolution), and the output signal becomes better. Also, the output signal of encoder is less affected by the intensity variation of encoder light. So the encoder is more stable.
(*) Satellite Prediction and Pre-processing Software. A new prediction software for satellites was introduced, and the accuracy of prediction for position and range of satellite is improved. The prediction accuracy of range for low orbit satellite reaches 20m and is better for LAGEOS. The accurate position prediction can increase the return rate from satellite. The accurate ranging prediction is in favor of narrowing range gate and reduce interference of background noise. The data pre-processing software picks up the useful data from large numbers of the raw observation data and generates normal point data for precise determination of orbit and other applications [6]. In addition, sometimes the laser produces two pulses at one firing, which might cause ranging bias for this pass. We compiled special software for dealing with two pulses, and the availability of observation data has been increased.

PROGRESS FOR DAYLIGHT TRACKING IN CHANGCHUN SLR SYSTEM

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This paper includes three parts about Changchun SLR system. First it summaries the Changchun SLR data quality and yield from data analysis centers: single shot rms, NP rms, long and short-term stability, data percentage and its ranks in ILRS. Second it introduces the problems and difficulties facing this system for daylight tracking -mount model, the separation of emitting and receiving parts of the telescope, control range gate, installing narrower filter. Third it presents some work which has been done in the system for daylight tracking: system stability improvement, laser stability improvement, mount model adoption, control system, etc. From these analysis and work which has been done, daylight tracking in Changchun SLR system is possible in the near future.

NEW DRIVE AND SERVO-CONTROL SYSTEM OF KUNMING SLR STATION

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A new project is now being carried on for Kunming SLR station at Yunnan Observatory: to upgrade drive and servo-control system of 1.2m telescope. The aim of the project is to improve the LEO satellite tracking capability. We will report the progresses and initial results of this project.

SAN FERNANDO SLR STATUS AND FUTURE OBJECTIVES.

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The San Fernando SLR is involved in a process of constant evolution. In the frame of the Spanish Government researching projects support, the station is being prepared to be able to extend to three tracking shifts, by using CSPAD not only during nightime but also during daylight. Some problems have to be overcome before we get this jump, i e. a more accurate control of the horizontal movement of the tellescope and a system to control the ray beam offset during daylight.
As soon as the station meet this goal, we will move to the next objective: the tracking of the highest satellites, ETALON, GLONASS, GPS and the coming GALILEO constellation.

SAN FERNANDO BAKER-NUNN CAMERA TRANSFORMATION

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The transformation of the San Fernando Baker-Nunn camera for robotic and remote CCD astrometry observation, started at December 2002. It's presented in this poster the present stage of that transformation and the scientific project for the realization of both systematic and specific observations campaigns. When the transformation will be finished, the camera will be moved to a new observation site at Catalan Pyrenees.
The ROA Baker-Nunn camera was originally a Smith modified Telescope of 50 cm of aperture and focal ratio f/1, designed in the 60's of twenty century for photographic observation of artificial satellites. Once the mechanic and optical transformation will be completed, the camera will provide a useful field of 5°x5°, and will observe in conventional and TDI modes, being able to react in a few seconds when an opportunity observation appears. In TDI mode, the camera will provide a 6000 square degrees scan every night, so it will be possible to cover, with a magnitude limit of V=20.5, the whole of North Hemisphere sky in only four or five useful nights.
Although the main astronomic interest of these surveys is to be used as databases, the scientific project includes the discovery and tracking of Solar System Objects: NEOS, PHAs, asteroids, comets and TNOs, transit extra solar planets detection; early detection of novas and supernovas and in general every program that can be benefited with the wide visual field of the camera and its high reaction capability.

MODERNIZATION OF THE BOROWIEC SLR SYSTEM

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The poster presents the process of quality improvement of the satellite laser ranging system in Borowiec performed in the period 2002-2003. The following new devices were installed: time interval counter STANFORD SR620, fast start photodiode and Constant Fraction Discriminator (CFD) TENNELEC TC-454 in start and stop channels. The realization consists several steps; installation and examination of a new counter, correction of the amplitude and shape of laser pulse by means of the fast photodiode, regulation of discriminator delay and levels for start and stop channels. All these works were finished in May 2003. The single shot precision and normal point precision was improved from 30 mm to 18 mm and from 7 mm to 4 mm respectively. Two centimeters systematic deviation of STANFORD time interval counter was eliminated. The better stability of the system delay vs amplitude of stop signal was observed. The accuracy of the Borowiec SLR data obtained from the results of the several orbital centers confirmed the improvement of the quality of the satellite laser ranging system in Borowiec.

LABORATORY TESTS AND CALIBRATION ON CHRONOMETRY FOR THE FRENCH TRANSPORTABLE LASER RANGING STATION.

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The very small (300 kg) French Transportable Laser Ranging Station (FTLRS) has been greatly proved now to be efficient and relevant both on reliability and accuracy for some months campaign in fields.
After many upgrades along three 8 months campaign, the accuracy was confirmed at the level of few millimeters by a collocation experiment performed at the Grasse observatory and the evaluation of two eight months set of data from Corsica in 2002 and Creta in 2003.
In order to validate easier and more accurate "no-bias" calibration method , we tested and calibrated Stanford chronometer in laboratory with respect to "Dassaut event timer" as a reference.
We describe in this poster method, test procedures, results and conclusion.

THE PERFORMANCE AND OBSERVATION OF MOBILE SYSTEM TROS-I IN CHINA

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The TROS-I(Transportable Ranging Observation System) is the new generation mobile SLR(Satellite Laser Ranging) system in China. The TROS-I was set up and began to track satellite in 2000. Since its outset of test operation, a lot of field observations were made successfully in Urumqi and Lhasa, western China and the observations filled up gap of SLR tracking in Asia. A series of field experiments has showed that the single shot precision of the system is about 1 to 3cm and about 10mm for the normal point. The largest ranging distance is 20,000km. The mobile system has achieved outstanding performance and extended remarkably the coverage of the existing SLR network from the eastern China to the western part. The ongoing and incoming observations by TROS-I will enhance greatly the ability of SLR in crustal movement monitoring in China. and contribute to precise orbit determination of scientific satellite missions. For instance, the Chinese satellites and other low orbit satellite such as GRACE and Champ.

The Current tectonic activities in China are intensive, evident by widespread deformation of various patterns and frequent strong earthquakes. At present, the application of GPS(Global Position System) measurements to tectonics have been remarkably increased in China and a great deal of advances on monitoring present crustal deformation has been made in the past decade[1]. SLR is also served as useful tool to addressing tectonic study, for instance, with a contribution to monitoring crustal movement by, verifying GPS-derived velocity field and maintaining the reference frame on a scale of continent. However, SLR capability is limited greatly by few stations and uneven configuration of the existing SLR network, majority of which are located in the eastern China. A mobile SLR system costs nearly as much and performs as outstandingly as a fixed system. Moreover, the mobile system has a great flexibility to set up sites on the request , therefore enhancing the ability in monitoring crustal movement and tracking various satellite missions for precise orbit determination It is logical step to develop a mobile system in China for strengthening the network configuration of the fixed SLR stations

In 1999, ISCEA(Institute of Seismology, China Earthquake Administration) offered a mobile SLR system-CTLRS for Xi'an institute of surveying and mapping[2,3].However, CTLRS didn't enter into a routine operation stage mobile for some reasons since then. In 2000, sponsored by the national scientific project CMONOC(Crustal Movement Observation Network Of China)[4], ISCEA developed a new generation mobile SLR system TROS-I[5]on a basis of the forerunner. A lot of upgrade were made in optical, timing and tracking subsystems. TROS-I started the first experimental observation at Beijing, Oct. 2000. It is proved that ranging precision of the TROS-I is 1-2cm for single shot, at a distance up to 20,000km and environment temperature for operation in the field is -20°C~+45°C. The whole performance reaches or exceeds the specifications proposed by designers. TROS-I has already been a standard station of IRLS network (International Ranging Laser Service), and has joined, as one of few mobile systems, in ILRS organization. We have acquired much high-quality data in Urumqi and Lhasa, China. Here we present the technical performance and the observation status of the TROS-I system.

Table. The summary of satellites and passes for four sites

Satellite	Beijing 7343 51 days	Urumqi 73558401 44 days	Lhasa 7356 150 days	Urumqi 73558402 173 days	Total Passes
LAGEOS-1,2	42	44	120	138	344
GPS35,36				6	6
GRACE-A,B				48	48
ENVISAT				55	55
GLONASS	44	2	14	27	87
ETALON	13	1	9	20	43
ERS-2	17	16	2	74	109
GFO	15	3	5	75	98
CHAMP	8	1	0	15	24
TOPEX,JASON	53	10	27	233	323
BE-C	43	2	10	82	137
AJISAI	60	0	32	133	225
STARLETT	22	0	7	107	136
STELLA	23	3	14	6	46
WESTPAC	4	3	0		7
Passes	344	85	244	1019	1688

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4 Niu Zhijun.Ma Zongjin,Chen Xinlian,etc.2002.Crustal Movement Observation Network of China(CMONOC).*Journal of Geodesy and Geodynamics*.**22**(3):88-93.

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INDIAN INTEREST ON S L R

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Indian Space Research Organisation (ISRO) is reviving the satellite Geodesy by opening a Space Geodesy Division in ISRO Telemetry, Tracking and Command Network (ISTRAC). ISRO is already operating a PRARE and a GPS station as a part of GeoForschungZentrm (G F Z) global network. There are recommendations for establishing SLR operation at the same site thereby elevating Bangalore as one of the fundamental reference station for geodesy and geodynamic studies. With the long experience ISRO has gained earlier on SLR operations, the data from the above techniques can be effectively used for geodetic purpose. As geodesy is a nascent field in India, an International workshop on Space Geodesy may be conducted at Bangalore which will provide more exposure and bring the national and international experts on a common platform to evolve utilization and research using these data for the next decade. ISRO will collaborate with academic and research institutions to evolve a strong and vibrant science group. ISRO has round the clock operations at SCC which is more suited for this programme and a regional data center can be established. SLR payload is already proposed for ISRO's future Remote Sensing satellites to gain on orbit accuracy. Laser altimeter is initiated for the Indian moon mission which is just kicked off.

THE MOUNT STROMLO SATELLITE LASER RANGING (SLR) SYSTEM LOCAL TIE CONNECTIONS BEFORE AND AFTER THE 2003 DESTRUCTIVE CANBERRA FIRES

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The integrity and strengths of multi-technique terrestrial reference frames such as ITRF2000 depend on the precisely measured and expressed local tie connection between space geodetic observing systems at co-located observatories. The destructive Canberra fires of January 2003 completely destroyed the Mount Stromlo Satellite Laser Ranging observatory including the SLR, DORIS and GPS located at the site. Fortunately, Geoscience Australia has routinely performed classical terrestrial surveys at Mount Stromlo, including surveys in 1999, 2002 and 2003 (post-fire). These surveys have included the determination of the SLR invariant point or IVP. Using existing undamaged survey pillars a consistent stable terrestrial network has been used to compute the relationship between the pre and post fire local tie connections. This relationship includes the millimetre level accurate connections and their associated variance covariance matrix and provides an un-broken contribution of the Mount Stromlo observatory to future terrestrial reference frames and other scientific outputs. Observational and analysis techniques are reviewed and results are given.

SGF HERSTMONCEUX: CURRENT STATUS AND FUTURE UPGRADES.

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The NERC Space Geodesy Facility (SGF) at Herstmonceux, UK features a very accurate and prolific ILRS SLR system, two IGS GNSS receivers and associated environmental monitoring systems. Automatic QC processes continually monitor the quality of all the observational products, the results of which are made available daily on the SGF website. Current funded plans for system upgrade include building an event timer based upon highly accurate timing modules and integration of a KHz solid-state laser system. Future possibilities include a proposal to place permanently on site an absolute gravimeter to compliment the space geodesy measurements and make possible new science from the site. In this poster we highlight the current diverse facilities at SGF and outline the future prospects.

CURRENT STATUS OF SAN JUAN SLR STATION IN ARGENTINA

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A new SLR station will be founded in the near future. The whole SLR systems were already developed completely and checked and accepted by the investor. Some introductions of configurations and characteristics for the systems will be in the paper. Also some test results of technique parameters and some achievements of testing observations will be introduced. The newest status of station constructions in Argentina and the timetables of the packing and shipment will be mentioned as well as in the paper.
The configurations:

Telescope.Reflecting; bi-axes;sender and receiver separated.
Control system only by mouse;tracking,predictions,preprocessing…
Servo system. Bi-close-loop control for velocity and position
Laser system. Nd:YAG passive mod-locked
Receiver: C-SPAD
Counter:SR-620
TV system:Intensifier+CCD.
Timing and frequency:HP58503A GPS time and frequency receiver.
Calibration:short distance target,out-install inside the dome.

SELF-MIXING OPTICAL DOPPLER RADIAL VELOCITY MEASUREMENTS & LASER LINK BUDGET: A PROSPECTIVE STUDY

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Optical Doppler measurements of satellite radial velocity would give complementary data to actual ranging measurements. This could help to further constraint the orbitography models. An analytical study of Doppler effect with expected link budget is presented. A tentative experimental setup using continuous laser with self-mixing detection seems very promising.

NEW APPLICATIONS

J. Degnan and Y. Fumin

Tuesday, June 8

10:30 - 12:30

- **Time Transfer by Laser Link T2l2**
  M. Ravet, E. Samain, R. Dalla, P. Aubry, J.M. Torre, J. Paris, J.F. Mangin, G.M. Lagarde

- **Time Transfer by Laser Pulses between Ground Stations**
  Y. Fumin, Z. Zhongping, C. Wanzhen, L. Xin, C. Juping, W. Bin

- **SLR2000C: An Autonomous Satellite Laser Ranging and Space-To-Ground Optical Communications Facility**
  J. Degnan, A. Seas, H. Donovan, T. Zagwodzki

- **Technical Concept for a European Laser Altimeter for Planetary Exploration**
  U. Schreiber, H. Michaelis, J. Oberst, I. Leike, T. Spohn

- **Laser Altimeter For Planetary Exploration**
  I. Prochazka, K. Hamal

- **Scientific Applications of Planetary Laser Altimeter Radiometry**
  M. Zuber, D. Smith

TIME TRANSFER BY LASER LINK T2L2

Muriel Ravet(1), Etienne Samain(1), Robert Dalla(1), Patrick Aubry(2), Jean Marie Torre(1), Jocelyn Paris(1), Jean François Mangin(1), Grégoire Martinot Lagarde(1)
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The T2L2 experiment allows the synchronisation of remote clocks on Earth, and the monitoring of a satellite clock, with a time stability of the order of 1 ps over 1000s and a time accuracy better than 100 ps. The principle is based on the propagation of light pulses between the clocks to synchronise. The ground segment is a satellite laser ranging station with a special instrumentation able to time light pulses accurately as compared to the ground clock to synchronize. The satellite payload comprises an optical package, and a time tagging unit connected to the space clock.
T2L2 was proposed for both low and high altitude, respectively in the framework of the CNES Micro satellite Myriade and in the framework of Galileo. The phase B study of the space segment was concluded at the beginning of 2004. This study permitted to design an instrument having a mass in the range of 10 kg and a power consumption of 40 W. It comprises the following elements :

- A detection unit based on an avalanche photo-diode working in a Geiger mode.
- A time tagging unit able to time the photo-diode output in the satellite clock time scale with a precision better than 3 ps.
- A high index corner cube (100mm diameter) having a large field of view.

A breadboard of the ground segment linked to the MeO Station (ex the Lunar laser ranging station) at Grasse and a prototype of the space segment (including the space optical components) allowed us to do a real simulation of the T2L2 time transfer. This simulation permitted to evaluate very precisely the global performances of the link with a realistic atmospheric propagation.

TIME TRANSFER BY LASER PULSES BETWEEN GROUND STATIONS

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The time transfer experiment by laser pulses between ground stations at Shanghai Observatory has been done in May-June, 2003. In fact, two stations, A and B, were located in same room and a mirror for reflecting the laser beams was set up at 250 meters away. Both two stations were equipped with hydrogen masers that were directly compared by a SR-620 timer continuously.
It is shown by the comparison results that the standard deviation of the mean of the clock differences determined by laser pulses is 24.1ps for a 100s interval, and the relative stability of frequency for two masers is 1.8×10^{-13}/200s. The uncertainty of measurement for the relative frequency differences by laser link for two masers is 4×10^{-15} during 6000 seconds. The comparison result by laser link is very coincident with the direct timing method.

SLR2000C: AN AUTONOMOUS SATELLITE LASER RANGING AND SPACE-TO-GROUND OPTICAL COMMUNICATIONS FACILITY

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NASA is currently field testing a prototype fifth generation satellite laser ranging system at the NASA Goddard Space Flight Center in Greenbelt, MD. Unlike past manned systems, SLR2000 is designed to be fully automated and eyesafe, transmits low energy subnanosecond pulses at high repetition rates (130 μJ @ 2 kHz = 260 mW), and has a demonstrated capability of detecting single photon returns from passive retroreflector arrays on satellites during both day and night operations. The system has been designed to track the current constellation of retroreflector-equipped satellites at altitudes between 300 km (LEO) and 20,000 km (GPS, GLONASS).
Recently, we investigated the possibilities for upgrading the SLR2000 system to permit several Gbps laser communications downlinks and several Mbps uplinks with Earth orbiting satellites in parallel with centimeter accuracy laser ranging operations. The combination of the two applications is highly synergistic since the requirements for autonomous satellite laser ranging/tracking and communications greatly overlap. In particular, the baseline SLR2000 system provides:

- Internet/modem/phone connections to support a variety of command and control functions (e.g. scheduling, updated orbital and time bias predicts, diagnostics, etc.), data transfer to a central processor, and internal instrument health and security monitors
- a "Smart" Meteorological Station which provides protection against local weather conditions (wind, precipitation, etc) and monitors ground visibility and cloud cover for efficient lasercom operations
- a GPS-disciplined Rubidium Time and Frequency Reference which yields accurate epoch times for reliable satellite acquisition as well as a stable clock reference for optical communications
- a 40 cm off-axis telescope with sufficient aperture to handle high bandwidth (2.5 Gbps per channel) optical com to Earth orbiting satellites using modest onboard laser powers (few watts at geosynchronous altitudes) but small enough to accommodate large phase front tilts due to the atmospheric effects or pointing errors in small aperture COTS lasercom detectors
- an arcsecond precision tracking mount augmented by automated star calibrations and high quality mount model for high accuracy absolute pointing (~2 arcsec RMS)
- a photon-counting quadrant detector with pointing feedback capability for locking onto and maximizing both the ranging and optical com signals
- a unique transceiver design with a passive transmit/receive switch which allows the transmitter and receiver to simultaneously utilize the full telescope aperture without limiting the two-way data transfer rate and allows for improved eye safety margins and narrower transmit beams

- Communication satellites can be easily included in SLR constellation for automatic updating of orbit predictions by the central processor for rapid target acquisition

Laser ranging off passive retroreflectors placed on the nadir-viewing face of communications satellite also provides: (1) a highly accurate orbit which implies less search time and faster target acquisition during subsequent orbits; (2) independent verification that the satellite has been acquired by the ground station; and (3) a bright beacon at 532 nm for the spaceborne lasercom terminal to lock onto.

The conceptual design of the proposed global network of upgraded SLR2000C (C = Communications) station, which will be described in the present paper, has followed the same developmental principles as the baseline SLR2000 system, i.e. maximum use of Commercial Off The Shelf (COTS) components, long life and reliability, and simplicity of operation. In particular, the proposed design leverages heavily off near-IR lasercom components being developed by the telecom industry at wavelengths near 1550 nm. The inclusion of a 10 Gbps (4 channels at 2.5 Gbps per channel) downlink and a 10 Mbps uplink lasercom capability is expected to increase the replicated cost by less than \$600K, or about 30% of the baseline station cost. Current applications under active investigation include a global space-to-ground optical communications network and a lunar mapping mission. Link analyses indicate that ranging to a geosynchronous satellite can be accomplished with a single, large aperture, hollow cube corner.

TECHNICAL CONCEPT FOR A EUROPEAN LASER ALTIMETER FOR PLANETARY EXPLORATION

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In the past year, our team has developed a concept for a high-performance Laser Altimeter for Planetary Exploration (LAPE) to fly on the BepiColombo Mercury Planetary Orbiter. The instrument must be capable to operate in harsh thermal environments and must also stay well within BepiColombos strict mass and power consumption constraints. In order to avoid excessive thermal loading and to keep the weight down we have chosen a small receiver telescope with 15cm aperture. The overall altimeter concept is mainly based on a high repetition rate microlaser and single photon detection by gated "Geigermode" APDs. The CW operation of the pump laser diodes of the microlaser avoids power switching and also makes capacitor banks unnecessary. These features lower the operation risk and mass requirements substantially. However, due to the high shot repetition rate the data processing becomes more complex and requires special considerations for binning and averaging the data. The basic performance of our concept has been evaluated by simulation. This talk outlines the altimeter design and discusses some of the simulation results.

LASER ALTIMETER FOR PLANETARY EXPLORATION

Ivan Prochazka, Karel Hamal

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We are reporting on the research and development of a Laser Altimeter for Planetary Exploration (LAPE). It has been selected by ESA as a key-technology for future planetary missions. The device has to provide altimetry in the range of 400 to 1400 km and 1m range resolution under rough environmental conditions - Sun illumination, high background radiation under extremely limited weight and power consumption allowances. The proposed LAPE is designed to be a modular test equipment to test critical components and technologies such as the microlaser source, the photon counting detector and its electronics. In particular the signal to noise ratio under various background light conditions in the near infrared and the detector sensitivity under various cooling concepts need to be characterised. Photon counting strategies for high repetition rate data acquisition, signal processing techniques and data reduction will be investigated. This project builds on our experience acquired within the Russian altimeter missions Mars '92 and in Lidar for the NASA Mars Polar Lander '98.

SCIENTIFIC APPLICATIONS OF PLANETARY LASER ALTIMETER RADIOMETRY

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Laser altimeters in addition to providing topographic data of planetary bodies are sometimes able to provide a measurement of the radiance of the object at the wavelength of the laser/detector. At Mars the laser altimeter on the Mars Global Surveyor spacecraft had an adjustable threshold for the detector so that return signals would be kept within a specified dynamic range. The threshold was adjusted according to the strength of the previous return and thus the variation in threshold became an approximate measure of the reflectance of Mars at 1064 nm over the illuminated laser spot on the surface of Mars, approximately 165 meters in diameter. This method we refer to as the active radiometry mode. After the laser ceased to operate in June 2001, and in between laser firings when the laser was operating, the detector measured the radiance of the solar illuminated surface at 1064 nm over the detector field of view of approximately 385 meters. This mode is referred to as the passive radiometry mode. In the active mode the instrument acquired radiometry at 1 Hz, with a S/N of about 10; in the passive mode the instrument acquired radiometry at 8 Hz with a S/N of about 100. We now have nearly 3 Mars-years (over 5 Earth-years) of high resolution passive radiometry of Mars at 1064 ±1 nm for spatial footprints of under 400 meters. These observations are being used to study the intrinsic brightness of Mars and to monitor the changes in the polar icecaps due to the seasonal exchange of CO_2 between the atmosphere and the surface. Fig 1 shows the two polar regions of Mars at the same time of year (Ls =260) when the sun is just below the equator and moving northwards. Note the difference in radiance of the two regions and the lack of symmetry of the south polar icecap.

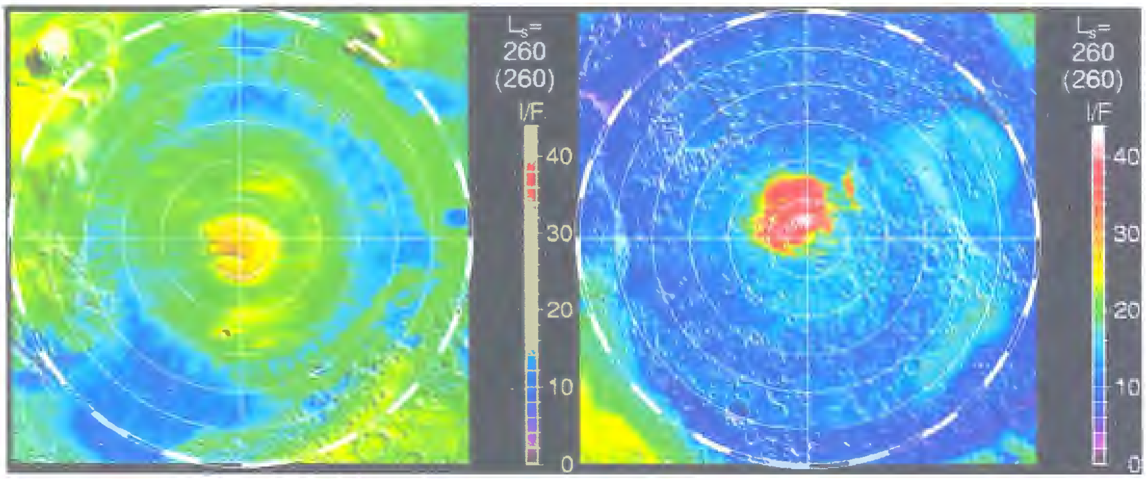

Fig 1. Radiometry at 1064 nm obtained by the laser altimeter at Mars during late Fall in the northern hemisphere (left chart) and late Spring in the southern hemisphere (right chart).

ATMOSPHERIC CORRECTION AND MULTIWAVELENGTH RANGING

C. Luceri and S. Riepl

Tuesday, June 8

14:00 - 16:00

- **Two-Wavelength Satellite Laser Ranging Experiment at Shanghai Observatory**
  Z, Zhongping, Y. Fumin, H. Jingfu, C. Wanzhen, C. Juping, L. Rendong

- **Real-Time Separation Atmospheric Tip-Tilt Signal from Lunar Surface**
  X. Yaoheng, G. Rui

- **Effects of the Atmosphere on the SLR Precision**
  J. Mulacova, K. Hamal, G. Kirchner, F. Koidl

- **Atmospheric Contribution to the Laser Ranging Jitter**
  L. Kral, I. Prochazka, G. Kirchner, F. Koidl

- **The Correction of SLR Data by the Nonlinear Dispersion of the Refraction Index of the Air**
  Y. Galkin, S. Stryukov, R. Tatevyan

- **Multiwavelength Refraction Modeling Improvements for SLR Observations**
  G. Hulley, E. Pavlis, V. Mendes, D. Pavlis

TWO-WAVELENGTH SATELLITE LASER RANGING EXPERIMENT AT SHANGHAI OBSERVATORY

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Combined with the existed satellite laser ranging system, an experimental system for two-wavelength SLR, including a dual-transmitting/receiving-channel is established at Shanghai station. Several low orbit satellites have been tracked with a pair of 0.532um/0.683um by the H2-Raman-shifting of the 0.532um simultaneously. The paper presents the system setup for two-wavelength ranging and preliminary analysis of ranging data. The future plan for improving two-wavelength ranging precision is put forward.

REAL-TIME SEPARATION ATMOSPHERIC TIP-TILT SIGNAL FROM LUNAR SURFACE

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Considering the atmospheric turbulence effects and the returned photon numbers in LLR, we think it's time to compensate turbulence effects in real-time in the LLR, especially for the effects of atmospheric tip-tilt. In this paper, we present the computation method of atmospheric tip-tilt from lunar surface, and the experiment results at Yunnan Observatory 1.2m telescope that use a small area near the retroreflector array on the lunar surface as an expanded source to detect and separate the atmospheric tip-tilt signal in real time.

EFFECTS OF THE ATMOSPHERE ON THE SLR PRECISION

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The influence of the atmosphere has been examined at the Graz SLR station using several targets: 6 km ground, retro on balloon and others. The precision of 6km ranging is 6 psec rms. The experimental results are compared with the Greenwood-Tarzano atmospheric fluctuations spectral model.

ATMOSPHERIC CONTRIBUTION TO THE LASER RANGING JITTER

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We are reporting on the theory and experiments related to the atmospheric fluctuations and their contribution to the laser ranging jitter. The millimeter precision ground target laser ranging at the 2 kHz repetition rate enabled us to reveal the short period atmospheric fluctuations contribution to the laser ranging error budget. The amplitude and the time spectrum have been investigated for the first time on the picosecond resolution level. The relation of this effect to the seeing conditions has been investigated.

THE CORRECTION OF SLR DATA BY THE NONLINEAR DISPERSION OF THE REFRACTION INDEX OF THE AIR

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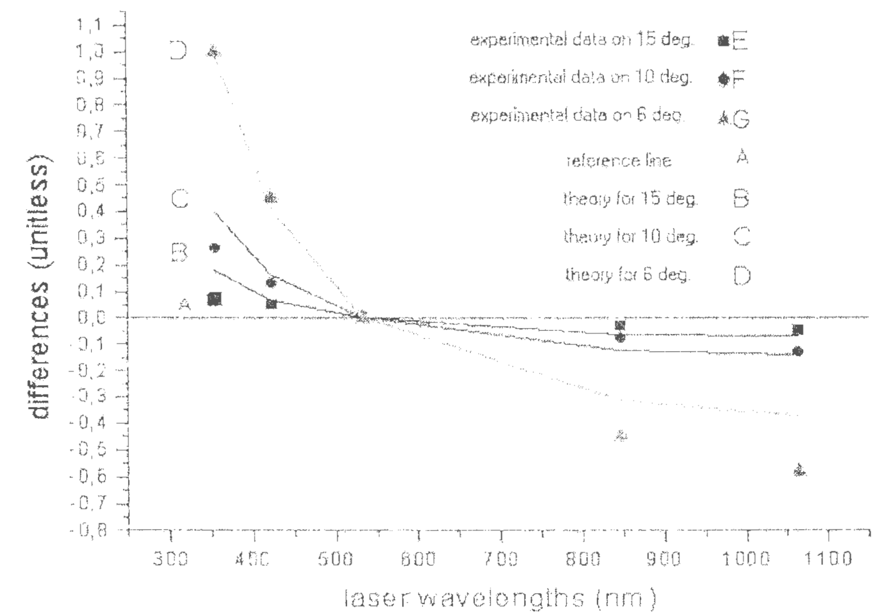
As it was shown recently /1/ the nonlinear dispersion of the refraction index of the air significant effects on results of SLR measurements even far away from absorption lines. This effect depends on laser parameters and measurement conditions. It is most importantly for the short laser pulses and small elevation angles of the measuring ray.
In this paper the estimation of effect for the homogenius sferical atmosphere is shown. The calculations are made for wavelengths as 1064, 847, 532, 423 and 355 nm in 6, 10 and 15 degrees of the elevation angles.
The results of calculations were rate set to known Mendes and Pavlis experimental data /2/ and compared with them. The comparision is shown on picture.



The average modulus of experimental differences is 0.22 units (relative unitless scale) after correction it bacame just 0.05.
The more detail initial data would improve result.

1. Galkin Yu.S., Tatevyan R.A. "Preliminary estimation of the atmospheric nonlinear frequency dispersion and absorption effects on the pulse SLR accuracy". Presented at the 13th ILR Workshop, 7-11 October, 2002, Washington DC, USA.
2. Mendes V.B., Pavlis E.C. "Atmospheric Refraction at Optical Wavelengths: Problems and Solutions". Presented at the 13th ILR Workshop, 7-11 October, 2002, Washington DC, USA.

MULTIWAVELENGTH REFRACTION MODELING IMPROVEMENTS FOR SLR OBSERVATIONS

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Atmospheric refraction is an important accuracy-limiting factor in the use of satellite laser ranging (SLR) for high-accuracy science applications. In most of these applications, and particularly for the establishment and monitoring of the TRF, of great interest is the stability of its scale and its implied height system. The modeling of atmospheric refraction in the analysis of SLR data comprises the determination of the delay in the zenith direction and subsequent projection to a given elevation angle, using a mapping function. Standard data analyses practices use the 1973 Marini-Murray model for both zenith delay determination and mapping. This model was tailored for a particular wavelength and is not suitable for all the wavelengths used in modern SLR systems. A recent study [Mendes et al., 2002] points out some limitations in that model, namely as regards the modeling of the elevation dependency of the zenith atmospheric delay (the mapping function component of the model). The mapping functions developed by Mendes et al. [2002] represent a significant improvement over the built-in mapping function the Marini-Murray model and other known mapping functions. Of particular interest is the ability of the new mapping functions to be used in combination with any zenith delay model, used to predict the atmospheric zenith delay. The next step is the development of more accurate zenith delay models applicable to the range of wavelengths used in modern SLR instrumentation (0.355 to 1.064 micrometers). Mendes and Pavlis [2002] concluded that current zenith delay models have errors at the millimeter level, which increase significantly at 0.355 micrometers, reflecting inadequacy in the dispersion formulae incorporated in the models. Using ray tracing through a large database of radiosonde data and the analysis if several years of SLR tracking data, we assess the new zenith delay models and mapping functions currently available. A new approach for the validation as well as the operational computation of atmospheric delays is presented, making use of the global fields produced by the AIRS instrument on NASA's AQUA satellite mission. We discuss the effect of using different types of input data to drive those models and the sensitivity of models and functions to changes in the wavelength and we give some recommendations towards a unification of practices and procedures in SLR data analysis.

SYSTEM CALIBRATION TECHNIQUES

U. Schreiber and F. Koidl

Tuesday, June 8

16:30 – 18:30

- **Five Target System Calibration**
  J.McK. Luck

- **New Internal Calibration Target at SGF Herstmonceux; Design and Results**
  D. Benham, P. Gibbs, V. Smith

- **MLRO Performance Characterization**
  G. Bianco, R. Sala, V. Luceri

- **Portable Pico Event Timer 2 Khz**
  K. Hamal, Ivan Prochazka

- **Tests of the Stability and Linearity of the A031et Event Timer at Graz Station**
  C. Selke, F. Koidl, G. Kirchner, L. Grunwaldt

- **Mount Model Stability**
  J.McK. Luck

- **Signal Strength Monitor for C-Spad Receiver**
  I. Prochazka, K. Hamal

FIVE TARGET SYSTEM CALIBRATION

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Stromlo SLR systems have five terrestrial calibration targets which are used in the MINICO method for verifying the assumptions made in calibrating the System delay. Four of the targets are mounted externally on pillars surrounding the System Reference Point (SRP) which is the telescope's intersection of axes. The fifth, which can act as a real-time internal target during satellite laser ranging, is the "Spider Retro" mounted on one of the vanes holding the secondary mirror. The full MINICO method involves ranging to all of these targets and estimating the horizontal coordinates (East & North) of the SRP, the distance between SRP and the Spider Retro, and the current System Delay.

From data kindly supplied by Geoscience Australia, the stability of the solutions over the 3½ year period from July 1999 to January 2003 will be presented, and application of the method in the new Stromlo-III system will be discussed.

NEW INTERNAL CALIBRATION TARGET AT SGF HERSTMONCEUX; DESIGN AND RESULTS

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Calibration is of course fundamental to realising the full potential accuracy of the satellite laser ranging technique. For several years, the SGF laser ranging system has used parallax-free targets at 100 and 400m distances for routine calibration and additionally for investigations into subtle distance-dependent effects in the Stanford counter cluster. However, the advantages of a close target include accurate environmental control, ease of access and, not least, availability during periods of poor weather. At SGF Herstmonceux we have designed and built a new calibration target fixed inside the laser telescope dome. This paper describes the mechanical features of the target, the difficulties encountered in arming the C-SPAD for such a close target and current investigations into observed small calibration differences between this new target and our existing long-range targets. We will attempt to show from experiments carried out on our additional moveable calibration target that this uncertainty in our measured calibration is caused by the behaviour at short range of the SR620 timers.

MLRO PERFORMANCE CHARACTERIZATION

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The Matera Laser Ranging Observatory (MLRO) has recently completed its warranty period and is now fully available for observational activities and further developments.
This presentation describes the system performances after three years of operations, including substantial debugging and fine tuning efforts, giving an estimate of the system ranging precision and efficiency, calibration stability, estimated biases, accuracy of estimated position, etcetera. Examples are given of the system behaviour on different geodetic satellites as well as on moon targets, along with a thorough description of the calibration procedures, options and capabilities.

PORTABLE PICO EVENT TIMER 2 kHz

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To make happy the "VIP SLR 2k Club" founded in Koetzting, October 2003 we have been developing the Pico Event Timer PET2k. The Portable version P-PET2k proofs the features when operating stand-by at the SLR station. The timing resolution is 1.2 psec, timing interval jitter below 3 psec, linearity better than 2.5 psec, the repetition rate up to 2 kHz. The P-PET2k is interfaced via a standard parallel communication port to a notebook. The P-PET2k contains the range gate generator, and the Signal Strength Monitor SSM for a C-SPAD based receiver.

TESTS OF THE STABILITY AND LINEARITY OF THE A031ET EVENT TIMER AT GRAZ STATION

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The Event Timer A031ET (made by the Institute of Electronics and Computer Science, University of Latvia, Riga) offers an interesting alternative to the widely used SR620 time-of-flight counters. In order to check for the linearity and stability of this instrument, a series of intercomparisons between the A031 and the E.T. at Graz SLR station (consisting of top-level Dassault modules) was performed. The obtained data covers the full range of time intervals which is of interest for SLR measurements (70 ns – 200 ms) and shows both excellent linearity and stability for the Riga Instrument. The different test methods and the results of the intercomparison between both event timers are discussed and useful hints for the optimum operation of the A031 are given.

MOUNT MODEL STABILITY

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The ability to acquire an invisible satellite target with minimum delay is vital in autonomous SLR systems as well as those manually operated. It is a particularly stringent requirement in LLR. Yet we don't want to waste hours doing star calibrations too often, so a Mount Model which yields 1 second of arc absolute accuracy for many months is needed.
Since the coefficients of the usual analytically-based Mount Model can yield useful diagnostic engineering information, it is important that they truly represent the errors being modeled, un-corrupted by aliasing from the other errors. There is a great deal of correlation between terms of the usual model, resulting in absurdly high condition numbers in the solution algorithm. For example, terms in secE and tanE are necessarily almost perfectly correlated.
The stability of the model is assessed firstly by the smallness of the pre-fit residuals of subsequent star calibrations, secondly by the variability of the solution coefficients over long periods of time, and thirdly by the condition numbers of the solutions. Some methods for reducing these are given.
The possibility of adding (not replacing) an orthogonal polynomial solution to the usual model is briefly discussed, using even-only or odd-only Legendre Polynomials. If anyone knows of a set of polynomials which are orthogonal over a hemisphere, please let me know!
Preliminary results from the new Mount Stromlo 1-metre telescope suggest that 1 second of arc stability is likely, which is probably due more to its excellent mechanical construction than to my algorithm improvements.

SIGNAL STRENGTH MONITOR FOR C-SPAD RECEIVER

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We are reporting on the possibility of echo signal strength monitoring in the C-SPAD based laser ranging systems. The operating principle and the experimental results will be presented. The Signal Strength Monitor SSM has been incorporated into the Portable Pico Event Timer 2k. The stand-alone electronics device has been designed, it determines the photon number estimate in a receiver chain based on C-SPAD detector package. The device is interfaced to a station computer via conventional serial link

ENGINEERING AND Q/C ANALYSIS I

R. Noomen and V. Glotov

Wednesday, June 9

09:00 – 10:30

- **Numerical Noise in Satellite Laser Ranging Data Processing**
  I. Prochazka, G. Kirchner

- **Is Your Performance being Ruined by Interpolation Errors?**
  J.McK. Luck

- **Engineering Data File Processing and Distribution**
  K. Salminsh

- **Herstmonceux Time Bias System as A Possible Real-Time QC Tool**
  I. Bayer, P. Gibbs, M. Wilkinson

NUMERICAL NOISE IN SATELLITE LASER RANGING DATA PROCESSING

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The SLR station Graz is producing millimeter precision ranging data at a return rate of 2 kHz. Ranging to terrestrial targets, the ranging precision below 1 mm is achieved, ranging to low pulse spreading satellite, the precision of 2-3 mm is achieved. These ranging data sets have been analyzed / smoothed using two different algorithms and working groups. The first solution has been based on the polynomial fitting, the second one on the orbital fitting approach. The computed o-c residuals have been compared for both solutions on a shot by shot basis. These differences are on single picosecond level, just indicating the order of magnitude of a numerical noise within the SLR data processing algorithms.

IS YOUR PERFORMANCE BEING RUINED BY INTERPOLATION ERRORS?

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The issue was raised by Werner Gurtner at the Washington Workshop 2002 and subsequently discussed at the Koetzting Workshop, 2003. Improper interpolation methods can have devastating effects on Normal Point accuracy, telescope pointing accuracy, and indeed any other performance measure.

The crux of the issue is the tabular interval used for interpolating the predictions used in generating the NPs. Almost as important is the choice of variables being interpolated. Using real prediction data generated from IRVs, it was found that errors due only to interpolation errors can amount to several NANOSECONDS in Normal Point values if the interval between data points is too large or the degree is too small. Similarly, such inadequacies can cause pointing errors of several HUNDREDS of seconds of arc, especially near maximum elevation, including quite low passes.

It is also demonstrated that interpolation into tables of topocentric Cartesian coordinates (East, North, Up) is far better than into tables of azimuth, elevation and range. Interpolation into tables of geocentric (X,Y,Z) would be even better.

A recommendation is proposed to amend the ILRS Normal Point Algorithm, Step (1) to include a specification of what constitutes "high precision predictions".

ENGINEERING DATA FILE PROCESSING AND DISTRIBUTION.

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Abstract.
Engineering data files (EDF) was proposed by the ILRS working group "Networks and Engineering" as an additional tool to the orbital analysis to deal with the SLR station long-term stability issues by maintaining a history of the local station parameters like calibration related values, meteorological data, ranging system data and checking out for the anomalies, comparing data among the SLR stations and exchange these data within SLR community. This paper discusses different ways how to work with the EDF files at the station and eventual data distribution procedures within the SLR community and implementation details as well.

HERSTMONCEUX TIME BIAS SYSTEM AS A POSSIBLE REAL-TIME QC TOOL

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For some years the NERC Space Geodesy Facility has been operating a daily QC service based on long and short-arc analysis of most of the satellites tracked by the ILRS network. The results continue to be presented each day on the Facility website. In addition, every hour the system at Herstmonceux downloads the latest hourly file of Normal Points from CDDIS. These observations are then used in an orbital solution to form a time bias (TB) relative to all available prediction sets for each individual pass. These individual TBs are then added to the global set and a polynomial fitted through them to produce the time bias functions that are made available to the ILRS network via a server at Zimmerwald, Switzerland. However, generation of these functions is sometimes complicated by the existence of poor data from one or more tracking stations. Much of the effort going into improving this TB service is currently centred on the development of an automatic system to detect and remove from the fit the poor data. As a bye-product and on a somewhat ad-hoc basis we pass the details of any poor data to HTSI who then report back to the station. We believe this system has the potential to send out a report automatically and directly to the station in near real-time and although not perfect would enable stations to detect gross problems quickly and complement other QC tools.

<u>ENGINEERING AND Q/C ANALYSIS II</u>

R. Noomen and V. Glotov

Wednesday, June 9

11:00 – 12:30

- **Determination of the Station Coordinates for Quality Control of the Satellite Laser Ranging Data**
  <u>S. Schillak</u>

- **Results of the SLR Tracking Data Quality Control During the Operational Processing**
  <u>H. Mueller</u>

- **MCC Analysis Procedure of the SLR Data Quality and Stations Performance**
  <u>V.Glotov</u>, N.Abylchatova, V.Mitrikas, M. Zinkovskiy

- **18 Years of Q/C Analysis at Delft University Of Technology**
  R. Noomen

DETERMINATION OF THE STATION COORDINATES FOR QUALITY CONTROL OF THE SATELLITE LASER RANGING DATA

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The continuous determination of the coordinates of the satellite laser ranging stations is one of the methods for quality control of the laser ranging data. This method reflect the quality of SLR data in the form of the station position stability, especially systematic effects (range bias) in vertical component and also quantity of normal points, which decided about standard deviation of coordinates determination. All position changes in the stable ITRF coordinates system are results of the SLR system errors or real position displacement (in the last three years Tateyama and Arequipa stations, or tectonic plate movements). The possibility of immediate comparison with results of GPS are also very important in this method. This paper is continuation of the previous papers presented on the last two laser Workshops and in the several publications.
The station coordinates were determined for LAGEOS-1 and LAGEOS-2 SLR data from monthly orbital arcs. The orbital arcs were determined on the basis of results of 15-17 fixed stations with very good quality of coordinates in ITRF2000 system. The orbital arc RMS was on a level of 1.8 cm. The paper presents results of coordinates determination for some choice stations, especially for comparison of two SLR systems in the same observatory and coordinates determination for new stations or upgrading of not correct ITRF2000 coordinates. The differences between topocentric coordinates obtained from orbital results and local geodetic tie were presented for three stations: Grasse (7835-7845) from 4.5-year period, Potsdam (7836-7841) from six months of 2003 and Maidanak (1864-1863) for the period from May 2002 to May 2003. The differences between normal points and coordinates for two colors for stations Zimmerwald (7810, 6810) and Concepcion (7405, 6405) were also presented. The coordinates and velocities of Riyadh station (7832) in ITRF2000 system has been corrected and Arabian tectonic plate motion were determined. The correct coordinates and velocities for this station are very important due to high quality and quantity of results. The coordinates determination and control of their stability for the new points were presented for FTLRS system: Ajaccio (7848) and Chania (7830). The example of continuous coordinates determination in the long period is Borowiec SLR station (7811). The stability of coordinates and the movement of Eurasian tectonic plate for this station were determined for the 10-year period from 1993.5 to 2003.5. The results of coordinates determination with the one month step for all SLR stations in the period 1999.0 – 2003.5 are available in Borowiec Observatory.

RESULTS OF THE SLR TRACKING DATA QUALITY CONTROL DURING THE OPERATIONAL PROCESSING

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Since June 2003 DGFI participates in the test phase of the operational production of station coordinates and earth orientation parameters of the ILRS Analysis Working Group. On a weekly basis we process tracking data to LAGEOS-1 and LAGEOS-2 and since March 2004 additionally to ETALON-1 and ETALON-2. During this processing we accomplish a number of quality checks, mainly detection of outliers and biases. The final biases and statistics are based on precise orbits. We will reveal the processing scheme and show some of the actual results.

MCC ANALYSIS PROCEDURE OF THE SLR DATA QUALITY AND STATIONS PERFORMANCE.

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MCC analysis procedure of the SLR LAGEOSes data quality and stations performance is based on the following standard steps:

- SLR data analysis and "bad" points rejection using automatic or/and manual procedure
- Precise orbits determination with the its real accuracy (rms) estimation
- The measurements residuals calculation for the separate passes
- The different statistic values calculation (ME, RMS, ORMS etc.)
- The attempt to interpret the measurement residuals as function of the Range Bias and Time Bias (depending on the both ascending and descending branches tracking during estimated pass)
- The forming of "MCC Residual Analysis Report" for ILRS stations

So there are three independent estimation values for the LAGEOSes passes quality that are calculated in the three data Analysis Centers: CSR, MCC and DUT. As a rule the large majority of the estimations for the passes quality are very close for the three data Analysis Centers. But sometimes, especially for the new or not too very stable SLR stations, there are the considerable differences between three Analysis Centers results. The main reasons of this situation are:

- Different co-ordinate sets of the SLR stations that were used in the Centers by SLR data analysis (Really it's very difficult to find the correct and precise co-ordinates for the unstable and "often modernized" stations)
- Incorrect attempts to interpret the measurement residuals as function of the Range Bias and Time Bias (Really it's very difficult or impossible for the short passes)
- Differences in the "bad" points rejection procedures for three Centers
- Differences in the final precise orbits

It's necessary for the SLR station staff support to find the fruitful procedure of the complex analysis of the different Analysis Centers results, especially in the questionable situations. In the report are given some proposals and recommendations for this problem solving.

18 YEARS OF Q/C ANALYSIS AT DELFT UNIVERSITY OF TECHNOLOGY

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The Quick-Look Data Analysis Center (QLDAC) was initiated in 1985, with the specific purpose of supporting the fields campaigns of the WEGENER/MEDLAS project. These campaigns took place in 1986, 1987, 1989 and 1992. Since then, the QC system has been refocused on more general services, like the semi-real time estimation of Earth Orientation Parameters and extending the quality control role to the global network of SLR stations, rather than just a limited number of mobile systems.
This paper will discuss the developments that the QLDAC has gone through with time. Aspects that will be addressed are organizational (software architecture), human (amount of people involved, interaction), technical (procedures, computation models) and performance-related (capabilities).

AUTOMATION AND CONTROL SYSTEMS

J. McGarry and W. Gurtner

Wednesday, June 9
14:00 – 15:30

- **Ray Matrix Approach for the Real Time Control of SLR2000 Optical Elements**
  J. Degnan

- **Remote Operation of GUTS-SLR**
  M. Sawabe, T. Uchimura, S. Murata, Y. Matsuoka, T. Oldham, J. Maloney

- **Consolidated Laser Ranging Prediction Format: Field Tests**
  R. Ricklefs

- **Zimmerwald Remote Control By Internet And Cellular Phone**
  W. Gurtner

RAY MATRIX APPROACH FOR THE REAL TIME CONTROL OF SLR2000 OPTICAL ELEMENTS

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NASA's SLR2000 is an autonomous, eye-safe, photon-counting satellite laser ranging (SLR) system. As such, it has some unique real-time control elements that are not generally found in conventional, high powered, manned systems. These include autonomous mechanisms and associated software for: (1) maintaining telescope focus over wide ambient temperature excursions; (2) conducting automated star calibrations and updating mathematical mount models; (3) centering the optical receiver field of view (FOV) on the satellite return; (4) varying transmitter beam divergence and point ahead; and (5) controlling the receiver spectral bandwidths and spatial FOV's. Most of these functions can be accomplished mathematically by utilizing a ray matrix approach. As an additional benefit, the ray matrix model can be used as a diagnostic tool to track the geometric size and orientation of beams and/or images anywhere in the system. Recent optical analyses of SLR2000 using the ray matrix model and experiences gained in satellite field experiments have led to some proposed modifications and simplifications to the optical transceiver, which will also be discussed.

As optical rays enter the SLR2000 transceiver from the Coude mount, they initially follow a common transmit/receive path, which later separates into three branches: (1) CCD star camera/autocollimator; (2) transmitter; and (3) quadrant detector range receiver (2 orthogonally polarized paths). Overall system focus is maintained over a wide ambient temperature range by a computer-controlled three-power beam expander located in the common transmit/receive path. The quality of the system focus is determined and controlled by the sharpness of star images in the CCD camera used for star calibrations. Periodic image checks ensure not only the sharpness of the star image for calibration but also the collimation of incoming and outgoing beams in other legs of the transceiver and the stability of the system focus at the variable aperture field stop (spatial filter).

For star calibrations, the ray model provides the information needed to automatically drive an off-axis star to the telescope optical axis. In particular, it provides the scale factor relating the magnitude of the position offset of the star image in the CCD camera to the magnitude of the angular offset in azimuth-elevation space. It also compensates for the star (or satellite) image orientation in the CCD camera as a function of the instantaneous mount azimuth-elevation angle.

In order to obtain an acceptable photon count rate for the higher satellites (e.g. LAGEOS, ETALON, GPS) while still meeting eye safety requirements at the telescope exit aperture, the SLR2000 beam divergence must be kept rather tight ($\pm$ 4.3 arcsec). On the other hand, for lower satellites, the angular uncertainty of the satellite position and the signal count rates are both relatively high and the beam divergence can therefore be relaxed to as much as $\pm$ 17 arcsec, provided solar background counts are not too high during daytime operations. Transmitter divergence is controlled in SLR2000 by defocusing a beam expander in the transmitter path. The magnification must also be chosen to optimize the transmitter beamwidth at the telescope exit aperture. For real time beam control, the ray model relates the desired quasi-Gaussian transmitter beam divergence at the telescope exit aperture to the amount of defocus (displacement of the negative lens) in the beam expander. A changing beam divergence must be accompanied by a corresponding change in the receiver FOV to avoid missing possible satellite returns. In the new design, the latter is adjusted via a stepper motor-controlled variable iris at the system field stop. The spectral bandwidth is controlled by a translation stage perpendicular to the optical path, which presently inserts one of the following into the receiver path: an open aperture (night), a 1 nm filter (twilight), or a 0.2 nm (daylight) filter. The wedge of these filters must be carefully controlled at the arcsecond level during manufacturing to avoid introducing angular biases and severe vignetting at the spatial field stop.

In high power manned systems, the operator can manually make two-axis corrections in the pointing angle in an attempt to peak the signal strengths off the satellite. This is not possible in a photon-counting system where the mean signal per pulse is normally much less than one photoelectron. Thus, SLR2000 uses a quadrant ranging detector, which, in addition to providing precise timing on single photoelectrons, informs the system computer of the quadrant that detected it. This information is accumulated over many laser fires (e.g. a frame interval) by a Correlation Range Receiver (CRR), which extracts the signal counts and discards the vast majority of background noise counts. The remaining counts (mostly signal) are then tallied by quadrant of occurrence, and the differences between quadrant counts are then used to compute a centroid for the count distribution during that frame. The ray model converts this centroid position into azimuth and elevation pointing corrections, which attempt to keep the satellite "image" centered in the receiver field of view thereby balancing the number of counts in the four quadrants.

Balancing the count distribution among the detector quadrants orients the receiver optical axis toward the "apparent" position of the satellite, i.e. where it was located one light transit time earlier when photons from the previous pulse were reflected from the satellite retroreflector array. For the tighter transmitter divergences, the point-ahead can sometimes exceed the beam divergence so that the future position of the satellite will fall outside the transmitted laser beam if left uncorrected for point-ahead. To achieve maximum illumination of the satellite and therefore the highest count rate on subsequent pulses, we must offset the transmitter axis from the "apparent" receiver axis by the angular travel accumulated by the satellite during the time it takes a light pulse to travel to and from the satellite. In SLR2000, the point-ahead correction is accomplished by two Risley prisms in the transmit leg of the transceiver. The ray model allows us to compute the proper orientation of the two Risleys in real time to produce the appropriate point-ahead as a function of the instantaneous azimuth and elevation rates. We have found that placement of the Risley prism pair at or near a pupil of the system (image of the telescope entrance aperture) can greatly reduce the amount of beam movement in the telescope exit aperture (and therefore transmitter beam vignetting) for large point-ahead angles. This will be especially important in the case of future interplanetary transponders where the point ahead can be quite large (e.g., 36 arcseconds for an Earth to Mars link).

REMOTE OPERATION OF GUTS-SLR

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The GUTS-SLR is operated by remote control from the Tsukuba Space Center (TKSC). An approximate distance between TKSC and SLR station is 1100km. 512-kbps communication line between SLR station and TKSC is used for system status, operational parameters and observation data transmission, 256-kbps for the transmission of surveillance monitor image.

The system has the following functions for remote control.

(1) In order to monitor the weather condition of SLR station, the weather monitoring system has a wind direction/anemometer and the raindrop sensor.

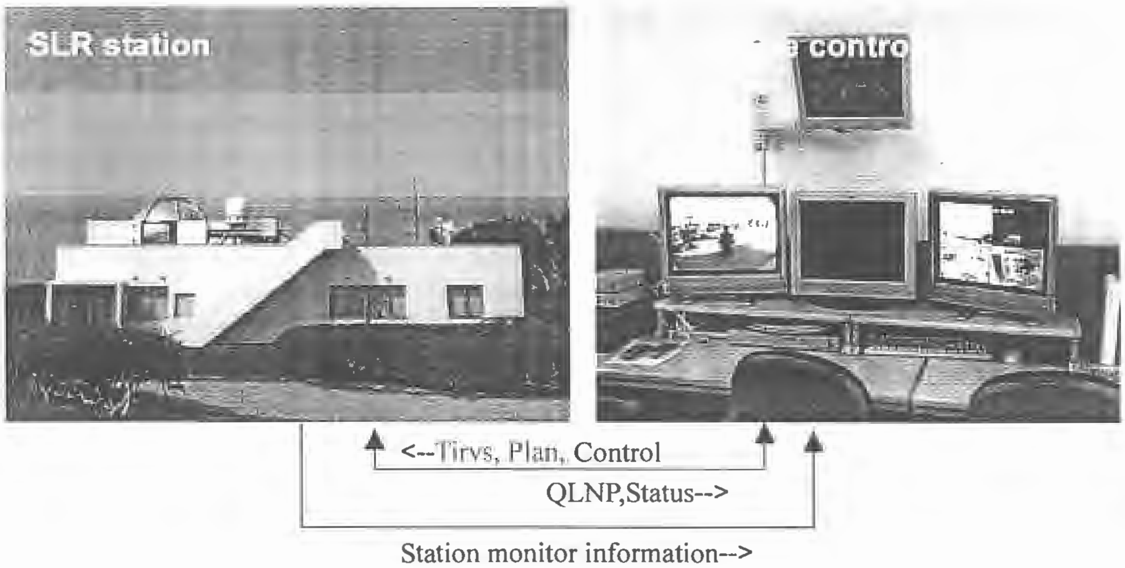
(2) The ITV camera is installed in order that a safe surveillance system may always carry out the monitor of around SLR observation building from the TKSC. Moreover, the door sensor which detects invasion into a building etc. is installed, and those signals are interface to the interlock of Laser directory.

(3) About the airplane surveillance, we installed the airplane surveillance radar which follows and operates on a telescope, and also installed the wide-view camera as the backup.

(4) As a measure for the solar interference in SLR daylight operation, evasion and defense are automatically performed by software and hardware. Therefore, the sunlight sensor is also equipped. An operator can be applied without being conscious of interference with the sun.

(5) In case of abnormalities such as the interruption of circuit between TKSC and SLR station, SLR station's computer detects abnormalities and it performs the stop of laser irradiation, movement at a telescopic home position, closing of a dome and set a standby mode until access comes from TKSC.

(6) The operation plan of SLR is planed automatically using the latest TIRV on daily basis.



CONSOLIDATED LASER RANGING PREDICTION FORMAT : FIELD TESTS

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The new ILRS consolidated ranging target prediction format has been developed by the ILRS Prediction Formats Study Group to provide a single format to encompass traditional artificial satellite and lunar ranging targets as well as proposed transponder targets on or around the moon and other planets. The primary benefit will be to allow any ranging station convenient access to ranging any of these target categories. In addition, the new format is designed so that predictions will not be subject to the inaccuracies inherent in tuning to a specific gravitational or drag model as found in the current IRV format.

While details of a few extensions to the format remain to be worked out, the core lunar and satellite components of the format are stable and have been subjected to a pilot study at MLRS. A discussion of the sources for the new predictions is presented, as is an analysis of the results of the ranging tests. Plans for future tests and implementation are also discussed.

ZIMMERWALD REMOTE CONTROL BY INTERNET AND CELLULAR PHONE

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The Zimmerwald Laser Station can be operated from a remote system using telnet and x-window clients, supervised using any web browser, and controlled to a certain extent by cellular phone. The paper describes the control possibilities available on the different media. The presentation will include online demonstrations depending on the current communication availabilities.

TARGETS, SIGNATURES AND BIASES I

G. Appleby and T. Otsubo

Thursday, June 10

09:00 – 10:30

- **Laser Retroreflector Array of Geostationary Satellite, ETS-VIII**
  M. Sawabe, T. Uchimura, A. Suzuki, H. Noda

- **Design of Laser Retro-Reflector Array and Laser Ranging Experiment for Shenzhou-IV Satellite**
  Y. Fumin, C. Wanzhen, Z. Zhongping, C. Juping, W. Yuanming

- **A New Approach for Mission Design for Geodetic Satellites**
  M. Lara

- **Lageos' Asymmetric Reflectivity**
  D. Arnold, G. Appleby

- **Centre-of-Mass Correction Issues: Towards mm-Ranging Accuracy**
  T. Otsubo and G. Appleby

LASER RETROREFLECTOR ARRAY OF GEOSTATIONARY SATELLITE, ETS-VIII

Mikio SAWABE, Takashi UCHIMURA, Akinobu SUZUKI, Hiroyuki NODA(1)
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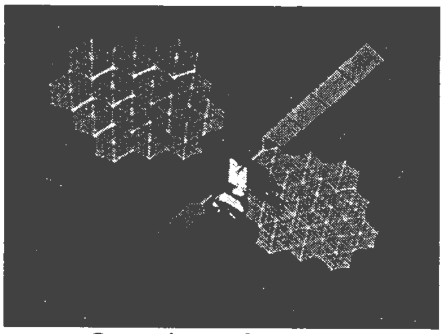
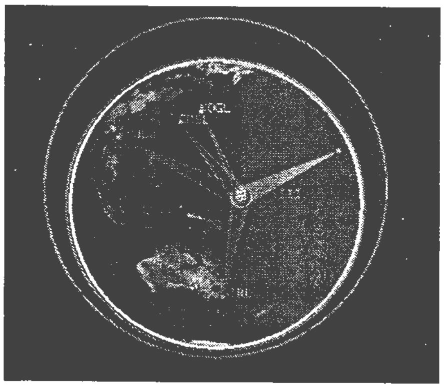
JAXA' Engineering Test Satellite-VIII (ETS-VIII) will conduct positioning experiments, combining the clock signals with GPS data, to study basic satellite positioning systems. It will be launched in 2005-2006 and located into the geostationary orbit at 146 degrees East.



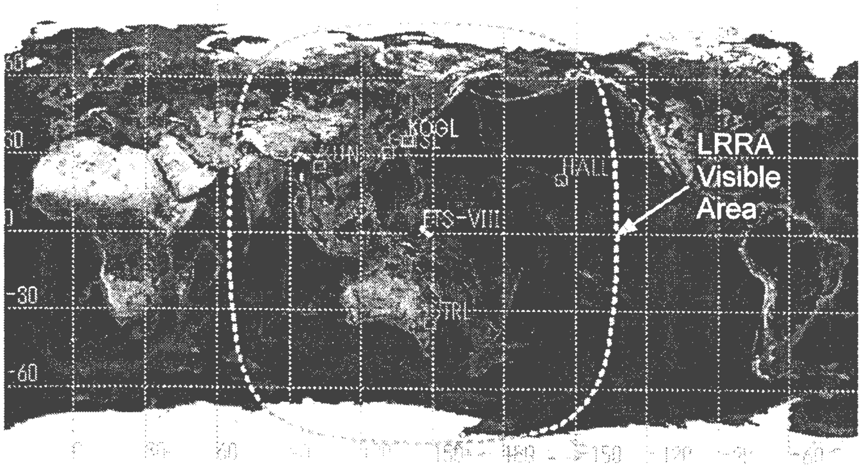
Overview of ETS-VIII

ETS-VIII will carry a high precise clock system, and also Laser Retroreflector Array (LRRA) that will be used for the evaluation of experiment results such as precise orbit determination and onboard clock estimation.

The LRRA consists of 36 corner-cubes which are contained within an envelope of 26cm x 30cm x 5cm. Its approximate weight is three kilograms. SLR stations in the Asia-Pacific region will be able to Laser-track to the ETS-VIII.
We will present an overview of ETS-VIII, LRRA and result of link budget analysis.



Proposed SLR configuration for ETS-VIII



FOV of the ETS-VIII LRRA and candidate SLR stations

DESIGN OF LASER RETRO-REFLECTOR ARRAY AND LASER RANGING EXPERIMENT FOR SHENZHOU-IV SATELLITE

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At the end of 2002, China launched a spaceship named "Shenzhou-IV", which was at an altitude of 350km and carried laser retro-reflector array(LRA) and other equipments. The LRA designed by Shanghai Observatory was used to support the precision orbit determinaton of the satellite.

The LRA with a diameter of 20cm are truncated cone-like with 9 corner cubes.

The formula for the effective area of the retro-reflector array with different inclination angles at arbitrary celestial zone was deduced in this paper.

5 Chinese SLR stations took part in the laser tracking of Shenzhou-IV satellite. Total 80 passes obtained, and the ranging precision is at the level of 1 to 2 cm for most passes, and averaging returns at the level of 300 observations per pass.

A NEW APPROACH FOR MISSION DESIGN FOR GEODETIC SATELLITES

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In the geodetic applications of an artificial satellite, associated measurements are frequently sampled along the ground track of the satellite's nadir point. The points where the ground track of a satellite intersects itself on the surface of the earth are called crossover points. Crossover points provide relevant measures in satellite geodesy, for instance in the calibration of a gravity field model[1] Techniques for the determination of crossover locations have been introduced in several studies. The relevant bibliography can be found in[2]

The ideal situation occurs when the satellite repeat its ground track on the surface of the Earth, and repeat ground track (RGT) configurations are therefore preferred. The procedure of mission design starts from the experiment requirements, which constrain the orbital parameters to a subset of limited values. Then a first order J_2 design is done as a rough estimate of the nominal solution. Further refinements of the orbital elements —usually in the presence of a medium degree zonal model, but sometimes including drag— will provide the nominal orbit.

The refinement procedure aerospace engineers normally use is based on trial and error interactive corrections that converge to a good nominal set of orbital elements; "good" meaning that the satellite does not drift substantially from the RGT. This refinement is done by a fine "tuning" of both the semimajor axes and the eccentricity in a manual iterative sequence.

On the contrary, it has been recently shown that periodic solutions exist for a zonal model of the artificial satellite when the problem is formulated in a synodic frame, i.e. a rotating frame attached to the planet[3]. These periodic orbits repeat exactly their ground track on the surface of the planet and, hence, are ideal candidates as nominal orbits for RGT missions.

In this communication we describe SADSaM, a software tool for computing RGT orbits. It is based on the continuation of families of periodic orbits. By assuming a zonal model for the gravitational potential, SADSaM deals with a two parameter problem: While the energy E determines the size (and period) of the orbit, the polar component □ of the angular momentum vector is related to its inclination —except for the critical inclination, where variations of □ imply variations in the eccentricity for fixed inclination. Therefore, for a given RGT the exploration of the (□, E)-plane allows to find the desired solution.

SADSaM is totally automatized: By simply introducing the RGT cycle between the nodal periods and nodal days as input, SADSaM provides the initial conditions of an exactly RGT orbit either sun synchronous or at the required inclination in just a few seconds —even for a high degree (zonal) gravitational model. Besides SADSaM provides the stability character of the RGT orbit and its averaged orbital elements.

We illustrate the usefulness of this tool computing nominal orbits for ERS-1, ENVISAT, and TOPEX/Poseidon, three satellites that are actually tracked by the laser station of ROA. We find that the orbital parameters provided by SADSaM are very close to the real mission parameters.

[1] Klokocnick, J, Wagner, CA (1994), Bull Geod 68: 100-188
[2] Kim, MC (1997), J of Geodesy 71: 749-767
[3] Lara, M (1999) J of the Astronautical Sciences 47:177-188

LAGEOS' ASYMMETRIC REFLECTIVITY

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Various investigators have attempted to identify the source of the asymmetric reflectivity effect on the LAGEOS satellites. The germanium cubes cause an asymmetry in the radiation pressure and thermal emissions from the satellite. However, the asymmetry due to the germanium cubes does not appear to be large enough to account for all the observed asymmetry. This paper presents various physical arguments in support of the hypothesis that the optical cubes may be primarily responsible for the asymmetry. Verifying this hypothesis would require relatively complex, but nevertheless feasible calculations. The paper also asserts that the deviation from a black body is not a correct physical model for studying the asymmetry.

CENTRE-OF-MASS CORRECTION ISSUES: TOWARDS MM-RANGING ACCURACY

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As reported in past workshops, the centre-of-mass correction for spherical satellites cannot be treated as a constant. It depends on the optical detectors and also on the observation policy. For single photon systems the correction is likely to be smaller than the widely used standard values; for instance 242 mm instead of 251 mm for LAGEOS. Also, for multi-photon systems, the correction depends upon the optical strength of each return pulse. We calculated the effect for LAGEOS, AJISAI and ETALON based on the actual characteristics and location of each reflector, and found that the centre-of-mass correction varies by about 1 cm for LAGEOS and by between 4 and 5 cm for AJISAI and ETALON.
The effect is, if only partially, detectable by precise orbit analysis. When we apply the standard centre-of-mass correction of 1010 mm for AJISAI, the Herstmonceux single-photon ranging data consistently has a positive apparent range bias of from 20 to 30 mm, which agrees well with our theoretical centre-of-mass correction of 985 mm (25 mm smaller than the standard one). Looking more carefully into the behaviour of the post-fit residuals as functions of return intensity (numbers of returns per normal point), most of the observations from Compensated-SPAD (C-SPAD) systems were found to have strong dependence on the intensity. The effect amounts to 40 mm peak to peak for AJISAI, again as predicted by our theoretical studies. In addition, some C-SPAD stations have small (~ 10 mm) intensity dependences for LAGEOS.
The hardware and operational differences between the laser-ranging systems causes system dependent centre-of-mass corrections, which analysts should take into account, for instance, by adjusting range biases for each station. On the other hand, station operators should themselves strive to keep such offsets constant by avoiding variable intensity in their laser returns, which inevitably leads to a variable bias that is almost impossible to remove. Otherwise, geodetic products such as station coordinates and the gravity constant GM are sure to be contaminated.

TARGETS, SIGNATURES AND BIASES II

T. Otsubo and G. Appleby

Thursday, June 10

11:00 – 12:00

- **Return Energy Estimates Derived from Normal Point and Full-Rate Laser Data**
  M. Wilkinson, G. Appleby

- **Centre-of-Mass Correction Issues: Determining Intensity Dependency at a Multi-Photon (Moblas-5) Station.**
  R. Carman, V. Noyes, T. Otsubo

- **Identifying Single Retro Tracks with a 2 Khz SLR System-Simulations and Actual Results**
  D. Arnold, G. Kirchner, F. Koidl

RETURN ENERGY ESTIMATES DERIVED FROM NORMAL POINT AND FULL-RATE LASER DATA

Matthew Wilkinson and Graham Appleby
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To fully understand and model Centre-of-Mass corrections for individual stations one needs to have an understanding of the levels and degree of variation of return energy for each station. Using NPs and FR data and knowledge of the laser repetition rates for each station we were able to estimate the return rates for different satellites for the major ILRS stations. These values were then investigated for repeatability and elevation dependence and some inferences made on relative CoM corrections appropriate for each station.

CENTRE-OF-MASS CORRECTION ISSUES: DETERMINING INTENSITY DEPENDENCY AT A MULTI-PHOTON (MOBLAS-5) STATION.

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As reported by T. Otsubo and G. Appleby at the workshop in Koetzting, in the drive towards mm ranging accuracy, the effects of signal intensity on centre-of-mass correction values needs to be evaluated. While some work has been done on data sets from single photon (Herstmonceux) and other C-SPAD stations, evaluation of the effect on multi-photon MCP systems still needed to be undertaken.

To determine the effect that varying return energy has on residuals, passes need to be taken using a special tracking regime. It involves varying the return energy via ND wheel, so that the level alternates between high and low throughout the pass. This was not as simple as we had assumed and took some practice to perfect.

So far three test passes have been taken, one Lageos-2, one Envisat and one Ajisai. We have also taken a set of calibrations employing the same methodology. Getting a significant dynamic separation on the strong/weak returns for Ajisai and Envisat was relatively simple due to the normally strong receive energies associated with these satellites. However we had to wait for good conditions (post summer dust), to get a good separation on Lageos2.

The passes were processed in three ways. Firstly the passes were processed normally and the ql data submitted. Secondly the raw data was delogged to give O-C vs time for all returns. Thirdly, each pass had its strong and weak segments separated and each part was processed separately.

Initial analysis of the passes shows good separation between strong and weak returns. Detailed analysis is now being done and results should be available shortly.

IDENTIFYING SINGLE RETRO TRACKS WITH A 2 KHZ SLR SYSTEM - SIMULATIONS AND ACTUAL RESULTS

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The new 2kHz SLR system at Graz can generate single photoelectron histograms in a short period of time. Plots of the range residuals vs. time show how the return pulse shape varies during a pass. Many satellites, including Lageos, appear to show single retro tracks. Computer simulations have been used to calculate return pulse shapes as the viewing angle on the array changes. Plots of the simulated data look very similar to plots of the actual data. The simulations indicate that the tracks can be single retros for small arrays, or groups of closely spaced retros for large arrays.

ADVANCED SYSTEMS AND TECHNIQUES

F. Pierron and H. Kunimori

Thursday, June 10
13:30 – 16:00

- **The New Mount Stromlo SLR System**
  B. Greene, C. Smith, Y. Gao, J. Cotter, C. Moore, R. Brunswick, C. Burman
- **Overview of Guts SLR Station**
  M. Sawabe, T. Uchimura, A. Suzuki, S. Murata, Y. Matsuoka, T. Oldham, J. Maloney
- **Early Satellite Tracking Results from SLR2000**
  J. McGarry, T. Zagwodzki, J. Degnan, P. Dunn, J. Cheek, D. Patterson, H. Donovan, A. Mann, A. Mallama, R. Ricklefs
- **Graz KHz SLR System: Design, Experiences and Results**
  G. Kirchner, F. Koidl
- **The SOS-W - A Two Colour Kilohertz SLR System**
  S. Riepl, W. Schlüter, R. Dassing, K.-H. Haufe, N. Brandl, P. Lauber, A. Neidhardt
- **A Compact, Totally Passive, Multi-Pass Slab Laser Amplifier Based on Stable, Degenerate Optical Resonators**
  J. Degnan
- **Recent Achievements in Detectors for Eye Safe Laser Ranging**
  I. Prochazka, K. Hamal
- **Advanced Techniques at the EOS Space Research Centre**
  B. Greene, C. Smith, Y. Gao, J. Cotter, C. Moore, I. Ritchie, C. Burman

THE NEW MOUNT STROMLO SLR SYSTEM

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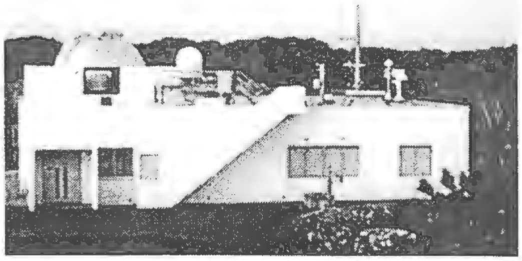
The Mount Stromlo SLR system was totally destroyed by fire on 19 January 2003. Construction of a new facility commenced on 4 July 2003. This system is now operational and undergoing final data testing before being re-integrated to the ILRS network.
The system includes new technology in the laser, telescope, and receiver systems that allow it to initially imitate the performance of the old system, and then progressively move forward to higher performance limits.
The specific characteristics of the new system, and its performance objectives, will be discussed.

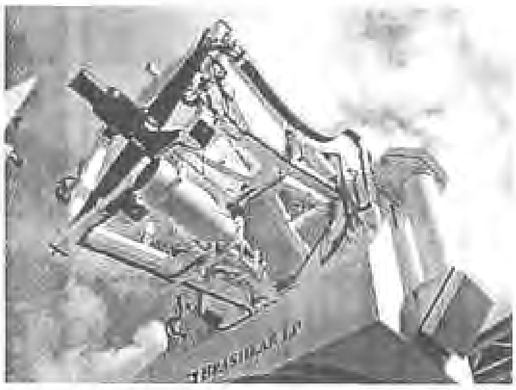
OVERVIEW OF GUTS SLR STATION

Mikio SAWABE, Takashi UCHIMURA, Akinobu SUZUKI (1)
Shigeru MURATA(2), Yoichi MATSUOKA(3), Thomas Oldham(4), Jeff Maloney(5)
(1)Japan Aerospace Exploration Agency.(2) NEC Corporation. (3) NEC TOSHIBA Space Corporation (4)Honeywell Technology Solutions, Inc. (5)Brashear LP
sawabe.mikio@jaxa.jp /Fax:+81-29-868-2990

Japan Aerospace Exploration Agency's (JAXA) Satellite Laser Ranging system (GUTS-SLR) has been completed in the spring of 2004. Its SLR station is located in Tanegashima Island, southern part of Kyushu.
GUTS-SLR has capability of ranging to various satellites from low earth orbit to geostationary orbit. The 1-meter Cassegrain telescope, with its associated 5 meters diameter Dome assembly will be used to precisely point the outgoing Laser beam and to acquisition the reflected signals from various targets with Az: 25 degrees/sec and El: 10 degrees/sec maximum slew rate. The Laser subsystem generates both 50mJ/pulse (for LEO) and 300mJ/pulse (for GEO) with wavelength of 532nm. The pulse width of Laser is designed to be 60 psec (for LEO) and 300 psec (for GEO) respectively in order to avoid the damage on the optical components. The ranging subsystem provides the optical interfacing hardware, range measurement electronics, standard frequency sources and system control signals needed for the SLR application.
The GUTS-SLR system will be able to range to LAGEOS satellites with a single-shot RMS of less than 10 mm RMS, less than 30 mm RMS for ETS-VIII (JAXA geostationary satellite).
The GUTS-SLR is operated by remote control from the Tsukuba Space Center (TKSC). An approximate distance between TKSC and SLR station is 1100km. 512-kbps communication line is used for transmission of system status, operational parameters and observation data, 256-kbps for the transmission of surveillance monitor image (ITV camera).
The operation of GUTS-SLR station will be kept almost autonomous manner according to the automatic sequence. Operator only intervenes in the initial power supply on/off, manipulate for the initial acquisition when the orbit prediction has an error and regular maintenance of system. An operational plan of the whole GUTS system is unitary planned by master control and operation planning subsystem, which is called COPs, and COPs also monitors operational conditions of each subsystem.



Exterior of GUTS-SLR facility



Exterior of 1m Telescope

EARLY SATELLITE TRACKING RESULTS FROM SLR2000

J. McGarry (1), T. Zagwodzki (1), J. Degnan (2), P. Dunn (3), J. Cheek (3), D. Patterson (4), H. Donovan (4), A. Mann (4), A. Mallama (3), R. Ricklefs (5)
(1) NASA Goddard Space Flight Center. (2) Sigma Space Corporation. (3) Raytheon Information Technology and Scientific Services. (4) Honeywell Technology Solutions Incorporated. (5) University of Texas at Austin.
Jan.McGarry@nasa.gov

NASA's SLR2000 was conceived as a totally automated, eye-safe, photon-counting, two-kilohertz satellite laser ranging (SLR) system. Prototype development of SLR2000 has been underway for the past several years at the Goddard Space Flight Center. These efforts recently culminated in successful satellite tracking. The authors now have an integrated semi-automated prototype system that can range to satellites and can perform many of its functions without operator intervention. Results from recent satellite and ground ranging experiments will be presented along with the current system status and plans for further development.

GRAZ KHZ SLR SYSTEM: DESIGN, EXPERIENCES AND RESULTS

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The new kHz SLR system at Graz is ranging to all satellites since October 2003; since that we have achieved almost all hoped-for improvements, as well as some not so expected results ...
The DPSSL (Diode Pumped Solid State Laser) starts with a SESAM (Semiconductor Saturable Absorber Mirror) seed oscillator, a regenerative amplifier and an additional post amplifier; it delivers up to 2 kHz pulses with about 400 µJ/shot @ 532 nm, and 10 ps pulse duration. The standard Time Walk Compensated C-SPAD is used as a detector, gated by a programmable Range Gate Generator, which is programmed into an Altera FGPA chip, achieving a resolution of < 500 ps, and an accuracy of < 1 ns. This FPGA chip also controls the laser firing commands, shifting them automatically if necessary to avoid overlaps between outgoing laser pulses and returning photons. Our event timer (Graz E.T., as described in Matera 2000), measures time-of-flight with 1.2 ps resolution.
The return rate of this system is – as expected – near 100 % for LEO satellites, resulting in up to > 1.000.000 returns per AJISAI pass; even from LAGEOS, we already got almost 400.000 returns in a single pass. Such high return rates deliver some 10.000 returns per NP for most satellites, producing much better defined NPs. Single shot RMS is about < 3 mm for satellites with low signature, but high return energy (GRACE, CHAMP etc.)
All fully automatic Real-Time algorithms (noise filtering, return identification, Range Gate and Time Bias settings, tracking optimisation / auto-track etc.) have been adapted to the kHz rates; due to the high repetition rate, these routines work faster and more reliable than before.
The system also detects tracks of single retros from various satellites, including Lageos.

THE SOS-W - A TWO COLOUR KILOHERTZ SLR SYSTEM

Stefan Riepl(1), Wolfgang Schlüter(1), Reiner Dassing(1), Karl-Heinz Haufe(1), Nikolaus Brandl(1), Pierre Lauber(2), Alexander Neidhardt(2).
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(2)Technische Universität München,Fundamentalstation Wettzell. D-93444 Közting, Germany

This paper presents the design of the newly envisaged SLR system termed Satellite Observing System Wettzell (SOS-W). The key idea behind the project is to provide support especially for low earth orbiting satellites, a kilohertz laser transmitter and a detection package being capable to perform two colour laser ranging. On completion the new system is mentioned to decrease the workload and configuration diversity of the WLRS, which, in turn, will be optimized for high altitude satellites and lunar laser ranging only.
The SOS-W will be set up at the existing SLR facility building of the Fundamentalstation Wettzell, which already hosted the Satellite Ranging System two decades ago. As the rough design of the transmit and receive optics is terminated, plans for modifying the building and dome installation are set up, which will allow a site installation and successive operation of the system during 2006.

A COMPACT, TOTALLY PASSIVE, MULTI-PASS SLAB LASER AMPLIFIER BASED ON STABLE, DEGENERATE OPTICAL RESONATORS

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New kilohertz satellite laser ranging systems rely on passively Q-switched microchip or SESAM laser oscillators for the generation of picosecond pulsewidths. Microchip lasers (e.g. SLR2000) typically generate several microjoule pulse energies at few kHz rates with pulsewidths on the order of a few hundred picoseconds whereas SESAM devices (e.g. Graz) can produce much shorter pulses between 10 and 25 psec but with significantly lower energies, typically sub-microjoule. Furthermore, at kHz fire rates, the amplifiers can be pumped with CW diode laser arrays for longer life and reliability, but the resulting gain per pass is relatively low compared to pulse-pumped systems. As a result, the pulse must pass through several stages of low-gain amplification in order to reach pulse energies of several hundred microjoules required for effective photon-counting. In the NASA SLR2000 system, the oscillator pulse is passed six times through a single amplifier head using three carefully aligned mirrors while, in the High-Q system used at Graz, the SESAM oscillator pulse is input to a relatively large regenerative amplifier with complex pulse switching electronics followed by a conventional amplifier.

We propose a totally passive, multipass amplifier based on the concept of "stable degenerate optical resonators". The characteristics of any optical resonator are defined by the radii of curvature of two mirrors, b_1 and b_2, and the distance d between them. The rays will not walk out of the resonator if the distance between the mirrors does not exceed the sum of the radii of curvature, i.e. if it satisfies the stability condition $0 \leq d \leq b_1 + b_2$. Each mirror separation can be associated with an integer N corresponding to the minimum number of resonator round trips required for an initial ray to complete a closed path. The integer N also corresponds to the number of discrete frequencies occupied by the full suite of TEM_{mnq} Hermite-Gaussian modes. If a laser amplifier slab is placed inside the resonator, the pulse makes 2N passes through the amplifier before returning to its point of entry. For each value of N, there are two types of ray paths, "ecliptic" or "non-ecliptic". Since non-ecliptic ray paths result in angularly separated input and output beams, they should not require isolation between the oscillator and amplifier or an independent means (e.g. polarization) of separating the input and output beams. Potential advantages of the technology include: (1) compact size, (2) simplicity and ease of alignment, (3) optical isolation of the oscillator and amplifier, (4) higher overall gain due to both an increased number of passes through the amplifier and better beam control, and (5) easy suppression of self-oscillations within the amplifier itself.

RECENT ACHIEVENTS IS DETECTORS FOR EYE SAFE LASER RANGING

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We are reporting on the latest results in the research and development of the solid state photon counters suitable for detecting individual photons in the near infrared wavelength region. The separate absorption and multiplication layer avalanche photodiode based on an InGaAs are one of the most promising candidates for the solid state photon counter for the eye safe laser ranging. Using the laboratory sample of InGaAs structure we have achieved the dark count rate as low as 30 kHz at modest temperature -60 C. The detector active area is 80 microns in diameter, its timing resolution of the detector is 1.8 nsec.

ADVANCED TECHNIQUES AT THE EOS SPACE RESEARCH CENTRE

B. Greene, C. Smith, Y. Gao, J. Cotter, C. Moore, I. Ritchie, C. Burman
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The EOS space Research Centre [SRC] at Mount Stromlo is committed to research and development of laser ranging and tracking, as well as related techniques in astronomy and optical communications.
The SRC has very substantial infrastructure and a super-set of tracking system characteristics. Current facilities include 100 cm and 180 cm telescopes, kW-class lasers, and AO systems. These capabilities allow the SRC to develop metrics for a wide range of operational tracking systems, including systems specifically designed for the accurate tracking of space debris.
An outline of EOS programs in space debris tracking and harm mitigation will be presented.

OPERATIONAL ISSUES

M. Pearlman and G. Kirchner

Thursday, June 10
16:30 – 18:30

- **Data Yield of the ILRS Global Network Over The Past Decade**
  E. Pavlis
- **The ILRS Report Card and Performance Charts**
  M. Torrence, V. Husson
- **Korea's First Satellite for Satellite Laser Ranging**
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DATA YIELD OF THE ILRS GLOBAL NETWORK OVER THE PAST DECADE

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We present an analysis of the data yield history of the ILRS Global Network. Variations due to seasonal, weekly and anthropogenic effects will be evaluated and quantified. The data from only the two LAGEOS satellites are used in this study. This ensures that the results are independent of other reasons for which an increase or decrease in data yield could be observed (e.g. targeted campaigns, loss of scientific interest in a particular target, ranging restrictions due to mission constraints, etc.). We will attempt to quantify the effect of the recent NASA-network reduction in the overall yield of the GLTN.

THE ILRS REPORT CARD AND PERFORMANCE CHARTS

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The Central Bureau has worked to fill the gap left by the change in staffing. A revised Report Card and performance charts are now available at the ILRS web site. Examples of these charts will be presented.

KOREA'S FIRST SATELLITE FOR SATELLITE LASER RANGING

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Science Technology Satellite-2 (STSAT-2) has been developed since Oct. 2002 as a sequel mission to KAISTSAT-4 (STSAT-1). STSAT-2 is schedule to be launched into an ellipsoidal orbit of 300km x 1500km in Dec. 2005, which seems to be delayed by two years, by the first Korea Satellite launch Vehicle KSLV-1. STSAT-2 has two payloads: a Lyman-alpha imaging solar telescope and a laser reflector array (LRA) for satellite laser ranging. The paper first presents a brief introduction to the STSAT-2 program. Then this paper presents the current status of the LRA development. In addition, we also introduce the beginning activities on SLR in Korea.

EUROLAS REAL TIME STATUS EXCHANGE

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Since 1999 about six European and one Australian laser stations routinely exchange their current tracking status on a real time basis. One application is the exchange of the real time-derived time bias after satellite acquisition, helping other stations to easier find the satellites in case of bad predictions. The paper discusses some experiences with this data exchange and encourages other stations to join these activities.

CDDIS ARCHIVE STRUCTURE SUPPORTING LASER RANGING DATA AND PRODUCTS

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The Crustal Dynamics Data Information System (CDDIS) has archived laser ranging data since 1982. These data consist of on-site normal points and full-rate. Products derived from the data are also archived in support of the ILRS. A new Linux-based server was recently procured for the CDDIS. During the transition to this new server, modifications to the on-line directory structure and filenames for the laser data archive will be made. This presentation will outline the new structure and filenames proposed for the CDDIS laser ranging archive.

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