Poster contributions

Jerry R. Wiant, Randy L. Ricklefs, Judit Gyorgyey Ries, Peter J. Shelus
Testing a Phillips 7186 16 Channel Time to Digital Converter

A Phillips 7186 16 Channel Time to Digital Converter has been modified and is being tested during times when the MLRS station is not actively gathering ranging data. The Phillips 7186 has the potential of becoming a critical component in the Time-of-flight timing system. Eventually the Phillips 7186 will be used in a test satellite pass. If the data quality is improved using the Phillips 7186 it will replace the Ortec TD811 8 channel Time Digitizer.

Bachir GOURINE
On use of Starlette and Stella laser measurements in determination of SLR stations coordinates and Earth Orientation Parameters (EOP)

The present work deals with the calculation of Laser stations coordinates and Earth Orientation Parameters (EOP) based on observations of Low Earth Orbit (LEO) satellites, namely Starlette (STL) and Stella (STA). The orbits of these satellites are less accurate because they are more affected by the gravitational and non-gravitational forces than those of high satellites as LAGEOS-I (LA1) and LAGEOS-II (LA2). The objective is to achieve good quality on the geodetic products by inter-satellite combination of Low and High satellites data. The orbit computation of the different satellites is performed with GINS software and the laser data processing is carried out by MATLO software, with consideration of a recent GRACE gravity model (Eigen_Grace-03s) in the processing, for a period of four years (between January 2002 and December 2005). The time series of the results are projected according to ITRF2000, by CATREF software, where the Helmert transformation parameters are obtained. We compare two series of solutions: LA1+LA2 (LL) only, and a four-satellite combination based on LA1+LA2+STL+STA (LLSS), in terms of quality of the weekly stations positions, EOP and Geocentre variations. The results presented show that the data obtained from LEO satellites such as Starlette and Stella can be successfully applied for precise determination of the SLR geodetic products. Key words: Satellite Laser Ranging (SLR), Starlette, Stella, LAGEOS-I/-II, LEO, EOP, Geocenter.

Mathis Bloßfeld, Horst Müller, Detlef Angermann
Adjustment of EOP and gravity field parameters from SLR observations

The combined estimation of Earth Orientation Parameters (EOP), orbit related parameters like Kepler elements or empirical accelerations and gravity field parameters are a big challenge since there are high correlations of these parameters among each other. SLR provides very accurate measurements of the first derivative of UT1, the length of day (LOD). Although this quantity is observed very precisely the correlation between LOD and the ascending node distort the estimated parameters systematically. The adjusted LOD shows a significant drift relative to IERS 08 C04 which is not severely linear. In this study we try to quantify the systematic effects induced by the high correlations mentioned above. Furthermore we discuss how the high correlations could be reduced by firstly using longer arc lengths or secondly including more than one satellite in the solution. The gained solutions are validated w.r.t. the IERS 08 C04 time series.

C. Schwatke, B. Forberg
The Eurolas Data Center (EDC) - Status Report 2009-2011

The EUROLAS Data Center (EDC) operates as ILRS Data Center for many years. In 2007 the new "Consolidated Laser Ranging Data (CRD)" format was introduced. The first stations started converting their quick-look and full-rate data to the new CRD in 2009. The conversion hasn't finished until now. Statistics show the development of the data holding of quick-look, full-rate, CRD, predictions and products at the EDC.

A. Jäggi, K. Sosnica, D. Thaller, G. Beutler
Validation and estimation of low-degree gravity field coefficients using LAGEOS

In the past three years the Bernese GPS Software has been extended with the capability to analyze Satellite Laser Ranging (SLR) data to geodetic satellites, e.g., LAGEOS and ETALON. LAGEOS orbit determination

using different Earth's gravity field models will be performed to generate weekly solutions (including station coordinates, satellite orbits, Earth rotation parameters, and range biases) and to assess the sensitivity of the LAGEOS orbits on the low-degree gravity field coefficients. The quality of the gravity field models will be validated by analyzing the orbital fits to the SLR data and by comparing orbit predictions with orbits estimated from measurements. Currently, the capability is under development to additionally estimate the gravity field coefficients together with all other relevant parameters with the Bernese GPS Software. We will present the status of the developments and show first results of weekly estimated gravity field coefficients.

Han Xingwei, Zhang Ziang, Song Qinli, Zhang Haitao, Shi Jianyong

Fulfillment of KHz SLR daylight tracking of Changchun station

This paper presents the solution of one key problem that is too much background noise in daylight, and it includes the smaller receiver field of view, application of narrow band interference filter and higher pointing stability. We successfully accomplished the KHz daylight SLR system——the tracking on Changchun SLR system. Then some results in daylight tracking of KHz system are showed in the paper and the observation results are analyzed. Key words: KHz SLR, daylight SLR, background noise

Han Xingwei, Zhang Ziang, Song Qingli, Zhang Haita

Experimental Daylight visibility of KHz Laser Beam

This paper introduces a new method of daylight visibility of KHz laser beam. Using the high sensitivity CCD surveil the daylight KHz laser beam imaging in real time. It requires the clear laser beam image according the spectrum filtering technology,exposure superposition,changing exposure time and image processing technology.It has important significance to enhance daylight KHz satellite laser ranging system in detecting ability. Key words: KHz SLR, back-scatter, high sensitivity CCD, LUT , exposure superposition

Yoon-Kyung Seo, Hyung-Chul Lim, Eun-Seo Park, Jong-Uk Park, Seung-Cheol Bang, Jin-Young Lee, Sung-Yeol Yu, Dong-Young Rew, Cheong Youn

Software Design and Development Status of ARGO-M Operation System

Software Design and Development Status of ARGO-M Operation System Yoon-Kyung Seo1, Hyung-Chul Lim1, Eun-Seo Park1, Jong-Uk Park1, Seung-Cheol Bang1, Jin-Young Lee1, Sung-Yeol Yu1, Dong-Young Rew2, Cheong Youn3 1Korea Astronomy and Space Science Institute, Korea 2Korea Aerospace Research Institute, Korea 3Chungnam National University, Korea E-mail : ykseo@kasi.re.kr A satellite laser ranging system named ARGO-M, Accurate Ranging System for Geodetic Observation-Mobile, is being developed by Korea Astronomy and Space Science Institute (KASI) and critical design review was finished on 31 March, 2011. During the design phase, SLR software logic for the ARGO-M operation was established with the aid of Graz SLR observatory in Austria. Software analysis and design include real-time control algorithm for laser ranging, data screening and processing algorithm for normal point formation. This paper describes software design feature and test results performed in order to examine the function of ARGO-M operation system. Furthermore, status of installation of operation support equipment and test running results of that equipment are presented in this paper.

Seung-Cheol Bang, Seong-Yeol Yu, Nung-hyun Ka, Yoon-Kyung Seo, Eun-Seo Park, Jin-Young Lee, Hyung-Chul Lim, JongUk-Park

Configuration of ARGO-M Optoelectronic Subsystem and its Performance Experiments

The optoelectronic subsystem of ARGO-M, Korean mobile SLR system, measures the start and stop epoch of laser pulses to compute the distance from a station to satellites, which includes SPD (Start Pulse Detector), C-SPAD, PDU (Pulse Distribution Unit), Event Timer and ISA card. The SPD developed by KASI (Korea Astronomy and Space Science Institute) and detects start laser signals on the transmitting optical table. C-SPAD from Peso-consulting in Czech is used to detect the returns from satellites. A032-ET from Institute of Electronics and Computer Science in Latvia measures the precise start and stop epoch. The PDU receive signals from SPD and C-SPAD deliver to A032-ET and ISA card, which was developed by KASI and performed various tests. ARGO-M runs KHz laser ranging which requires a fast optoelectronic control of RG generation and laser fire command. For these missions, ARGO-M uses the ISA card which was developed by Graz in Austria and consists of 500-ps internal Event Timer, RG generator and the laser fire controller. The experiment based on components was performed to guarantee and validate the performance of all components belonging to the optoelectronic subsystem. In addition, the experiment of the integrated optoelectronic subsystem including the ground target was also carried out for the functional and performance verification of ARGO-M in the laboratory by using the laser with 15 ps pulse width. In this study,

the design and performance test results are provided for SPD, PDU and Event timer. And the test results of the integrated optoelectronic subsystem is also presented with its configuration and analyzed.

D. Thaller, K. Sosnica, R. Dach, A. Jäggi, G. Beutler

LAGEOS-ETALON solutions using the Bernese Software

During the last three years, the Bernese Software has been extended with the capability to analyze SLR data to geodetic satellites, e.g., LAGEOS and ETALON. SLR data to LAGEOS and ETALON have been processed to obtain weekly solutions including station coordinates, satellite orbits, Earth rotation parameters (ERPs) and range biases. We study the stability of the orbit estimation by analyzing the orbit parameters. In addition, we validate the quality of the orbit predictions over one week by comparing the estimated orbit with the predicted orbit based on data of the preceding week. This comparison validates the quality of the orbit modeling used for the SLR analysis. The estimated ERP series will be compared to other time series, e.g., derived from GNSS data analysis or the official IERS C04 series. Different a priori models and parameterization are used in the analysis and their impact on the weekly solutions is studied. The models of interest are, e.g., ocean tidal loading or atmospheric loading. In addition, different parameterizations of the ERPs will be tested and compared: the standard ILRS parameterization using constant pole offsets per day (resulting in jumps at the day boundaries), and the piece-wise linear parameterization used in the Bernese Software for the GNSS solutions (including continuity at the day boundaries).

Eunseo Park, Young-Rok Kim, Hyung-Chul Lim, Sang-Young Park

A Preliminary Research of Precise Orbital and Geodetic Parameter Estimation System Using SLR Data

Korea Astronomy & Space Science Institute (KASI) has been developing SLR system. The name of the Korean SLR system is ARGO(Accurate Ranging system for Geodetic Observation) and the final goal of ARGO project is to develop two SLR systems, a 40cm mobile SLR system (ARGO-M) and a 1m fixed system (ARGO-F). ARGO-M will be developed by 2011 and then ARGO-F by 2014. The main applications of ARGO are precise orbit determination, space geodesy and space tracking. For the applications, we performed a preliminarily research to develope a precise orbital and geodetic parameter estimation system using SLR data, which was cooperated with ACL(Astrodynamics and Control Lab.) in Yonsei University. The feasibility study of estimation system development was implemented and we conducted a precise orbit determination system. The estimation system is consisted of dynamic, measurement models, and estimation algorithms. The dynamic models include geopotential perturbation, gravity of planets, solid earth tide, ocean tide, dynamic polar motion, relativistic effect, empirical acceleration, atmospheric drag, solar radiation pressure, and earth albedo pressure. A tropospheric delay and satellite body-fixed offset of the SLR array phase center are also considered as measurement models. The least squares filter is used for estimation algorithm. In this presentation, the structure of the developed estimation system is described and the orbit determination results using SLR data are analyzed.

Arsov K. Poutanen M. Raja-Halli A. Näränen J.

SLR station renovation in Metsähovi

This poster deals mainly with the improvement/renovation of our old SLR system. In 2006 it was made a decision to purchase a modern kHz laser and a contract was made with the High Q Laser Production GmbH of Austria. The laser ordered is a diode-pumped Nd:VAN solid state laser with the pulse rate up to 2 kHz and the pulse energy > 0.5 mJ. The laser is of the same type what e.g. Graz and Herstmonceux are currently using. The complete renovation of our old SLR system is on the way, including the 1 m telescope the primary mirror has been re-coated, new motors and encoders have been purchased and are currently in the implementation as well as an optical/mechanical solution for a separate beam path for outgoing and incoming beam is under implementation. Unfortunately the old telescope software due to these changes is not anymore operable, so complete writing of a new telescope controlling software is also ongoing. At the same time, software capable of kHz data tracking is under development. We replaced our old PMT detector with a digital C-Spad from the Czech Republic capable of handling KHz data and it is currently under development. For the timing, we purchased a new A032-ET event timer from Riga and also software implementation regarding the interaction with a032-ET is ongoing. For the gating, we implemented our own fpga based SLR controller and it is fully implemented into our SLR operational software. The timing and Meteo servers are completely renewed with a new GPS timing receiver together with the Hydrogen Maser signal and a new meteo server is being designed and implemented together with the timing server. Currently, a software module incorporating and controlling all of the abovementioned hardware is being under development, together with “smart” session planner as an integral part of our new SLR operational

software. The platform chosen is Windows Vista and the programming language is visual C++ with the usage of the MFC libraries. Parallel to the renovation of the 1 m telescope, we are seeking funding for a new telescope and dome to host the 2 kHz system. If succeeded, we hope to continue to use the 1 m telescope with a slower but a more powerful laser for MEO type satellites, including current and future GNSS.

Sung-Yeol Yu, Hyung-Chul Lim, Eunseo Park, Seung-Cheol Bang, Yoon-Kyung Seo

Container and Dome Development Status of Korean Mobile SLR System

Korea Astronomy and Space Science Institute (KASI) has been promoting the first SLR system development project named ARGO (Accurate Ranging system for Geodetic Observation) in Korea since 2008. The ARGO's final goal is to make one mobile SLR system and one fixed SLR system. Currently we are developing the 40 cm mobile SLR system, ARGO-M. The ARGO-M is composed of five subsystems: optical subsystem, Opto-electrical subsystem, laser subsystem, tracking mount subsystem, operation subsystem and container/dome subsystem (CDS). The CDS is consist of dome, container and ground target, which is designed to protect inner devices such as telescope and laser system from outer environments and transport them easily from one to the other site. The dome is an astronomical clamshell type and is made up 6 pieces, whose four pieces open and close by a winch system using iron cables except for 2 bottom pieces that are fastened on the base. The container is divided into 3 rooms, a laser room, an operation room and an accessory room. ARGO-M container has a similar type to the commercial one but its size is a little larger than the commercial product only in the length and width. The ground target is installed in the dome for the precise ground calibration. In this paper, the requirements and detailed design of CDS are provided and current status and future plan are also discussed.

Igor Yu. Ignatenko

Method of comparison laser locator with standard of length.

In this article, there is description of our method of comparison laser location station with national state standard of length. We produce comparison by comparison standard in several steps. Comparison standard and retroreflector are calibrate on national state standard and then transfer on calibrating basis. After this, final distance between reference point of laser range instrumentation and geodetic center, which determine calibrating basis, measured. By results of measurements, additive constant of SLR-system is determined.

F. Deleflie2,1, D. Coulot3, P. Bonnefond1

Positioning of the French Transportable Laser Ranging Station (FTLRS) over the 2002, 2005, 2008, calibration campaigns in Corsica

The French Transportable Laser Ranging Station was specifically developed by CNES, IGN, and OCA (GRGS) to make some calibration experiment of radars on board altimetric satellites such as Jason-1, & -2. It has to be located close to the satellite trajectory projected on the Earth surface, near a place equipped with a GPS buoy or a maregraph.In this paper, we will analyse the whole set of SLR data acquired by the FTLRS during the last three campaigns in Corsica in 2002, 2005 and 2008. More specifically, we show the impact on the positioning of the number of data, and of the kind of orbits that is used for the positioning, based on low altitude satellites (Starlette, Stella), or high altitude satellites (LAGEIS-1, LAGEOS-2). Moreover, we will show the differences induced by the change of a priori TRF (ITRF2005 or ITRF2008).

D. O'Gara, E. Kiernan-Olson, C. Giebink, D. Summers

Implementation of the LASER Traffic Control System at the Haleakala Observatories

The University of Hawai'i Institute for Astronomy Haleakala Observatories (HO) was for many years occupied only by Mees Observatory and the LURE Laser Ranging Observatory. Since Mees is a solar observatory, the laser system at LURE could operate at night without disturbing other science operations. Since 2000, several astronomical observatories have been built at HO, and more are being planned. Laser ranging operations ceased at LURE, but is now being carried out by the Transportable Laser Ranging System (TLRS-4). In order to prevent scattered laser light from interfering with the science operations of the optical observatories, HO is implementing a version of the Laser Traffic Control System (LTCS). W.M. Keck Observatory primarily developed the LTCS, with additional support provided by several other Mauna Kea observatories. The LTCS can predict when telescopes and laser beams will enter each other's field of view, allowing the observatories to take preventative action. The system currently supports laser guide star adaptive optics (AO) operations at Mauna Kea Hawaii, the Canary Islands (Spain), and in Chile. This poster paper will discuss the features of the LTCS, the limitations when SLR observatories are included in the current system, and the implementation of a test system at the Haleakala Observatories.

Chen Juping, Zhang Zhongping, Wu Zhibo, Zhang Haifeng, Li Pu, Yang Fumin
Progress in KHz SLR and laser ranging to un-cooperative space targets at Shanghai Station

Shanghai SLR station has been implementing routinely kHz repetition SLR by using kHz repetition laser with picosecond's pulse-width and high-precision Event Timer, designing nanosecond accuracy of Range Gate Generator with event mode and back-scattering avoiding circuit, developing real-time control software and data pre-processing software, since October 2009, The paper presents the progress in KHz SLR at Shanghai station, including ranging to the LEO, HEO, synchronized satellites at nighttime and daylight laser ranging for low-Earth orbit satellites. In addition, some new measuring results and progress of un-cooperative space target laser ranging at Shanghai Station are also showed in this paper.

A.Finkelstein, I.Gayazov, V.Shargorodsky, S.Smolentsev, V.Mitryaev
Installing SLR systems at the "Quasar" VLBI network observatories

The Russian VLBI network "Quasar" consisting of three observatories (Svetloe, Zelenchukskaya and Badary) carries out regular VLBI observations under both IVS and national programs. There are co-located IGS stations performing continuous GPS and GLONASS observations at the observatories and DORIS system at the Badary observatory. In 2011 the Russian satellite laser ranging system "Sazhen-TM" will be installed at all observatories of the "Quasar" network. "Sazhen-TM" has the optical system with a 25 cm diameter and is supplied with the laser system producing a laser pulse with duration 150 ps and frequency 300 Hz. The system is capable of ranging laser retroreflector satellites at 400-23000 km height. The accuracy of normal point range data is expected to be at 1 cm level. The technical characteristics of the "Sazhen-TM" system, the timeline of the installation process, and the co-location of observational techniques at the observatories are presented.

Hiroo Kunimori (NICT) and Koji Ohi (TTC Inc.)
Software and operational status of Koganei kHz Ranging Engine (KRE)

We present the current status about the new ranging system named KRE (KOGANEI kHz Ranging Engine) and software developments at NICT Koganei. The Koganei or Tokyo 7308 has been in operation using a manufacture's propriety ranging engine so called Master Ranging Control System (MRCS-ver.KSP) since 2002 when it was upgraded from MRCS old version since 1990. Replacement of ranging engine is being undertaken by the reason that it is not only old enough to maintain but also functionality could not accept high repetition rate as well as enhancement of software for user's own purpose and application. We have developed instruments KRE for the clear-to-user interface and specifications, correspondence up to 2kHz of repetition rate. The KRE consists of two core hardware: Range Gate Generator (RGG), Event Timer (ET) and software group to treat all ranging system and peripheral device via network. Based on FPGA RGG plays a key role of various timing control. ET, a product made in Latvia which records the epoch time of the input pulses. Time and frequency input to KRE is the standard 1PPS and 10MHz from clock source of the sites, selectable between UTC-NICT and GPS. Software integrates the controls of RGG and ET, trigger control, data gatherings of various laser subsystem, and modules on laser table, as well as the meteorological subsystem. An integrated XML-based database has been introduced to maintain configurations and various parameters in the system. Files and parameters used in old software system can be handled as well for transition to new system. A 2kHz laser of higher power but longer pulse width than existing pico-second ranging laser will be introduced and it combines with the laser of 20Hz, and system is capable of ranging to the moon.

Igor Yu. Ignatenko, Vitaliy G. Palchikov, Anatoly G. Zhestkov
New generation of the SLR station "Mendeleevo".

The main purpose of this paper is an analysis of the present state of things works a recreating the SLR station "Mendeleevo" at National Research Institute for Physical-Technical and Radiotechnical Measurements (VNIIFTRI) and creating new SLR station at our East-Siberian Branch of VNIIFTRI in Irkutsk city. These stations have the similar equipment, in particular: the laser location system produced by Open Joint-stock Company «Research-and-Production Corporation «Precision Systems and Instruments» (Moscow), the time and frequency standards (H-masers), precise gravimeters and GPS/GLONASS receivers. The metrology requirements of the present SLR systems are analysed. We also detail our plans to make the first precise measurements.

Krzysztof Sosnica, Daniela Thaller, Rolf Dach, Adrian Jäggi, and Gerhard Beutler
Availability of SLR Normal Points at ILRS Data Centers

SLR observations in normal point format are available from two ILRS global data centers, namely CDDIS and EDC. The data are organized in daily and monthly files. The centers have different management philosophies. In CDDIS the data are released within one day, whereas EDC publishes date in daily and monthly batches, containing observations stemming exactly from one particular day or month, respectively. After station upgrades, laser or telescope repairs, data from those stations are sent into “quarantine”, which may last for half a year or even longer. CDDIS publishes SLR observations from several previous months in one file (labeled with the release date), whereas EDC publishes the observations attached to the files labeled with the date of the measurement. We prepare and present the statistics concerning data availability in the two data centers for the period 1994-2011, as well as small inconsistencies in quantity of normal point observations from EDC and CDDIS. The total number of measurements to LAGEOS-1,-2, ETALON-1,-2, GPS-35,-36, and to about 50 GLONASS satellites will also be presented. We will address the number of observations gathered by every ILRS station for the particular years and the global distribution of the stations with an assessment of the stations’ quality and quantity of data. In conclusion we will show the data distribution along the groundtracks of geodetic satellites.

Raja-Halli A., Näränen J., Lapushka K., Arsov K., Poutanen M.
Recent upgrades on the Metsähovi satellite laser ranging telescope

Metsähovi research station is the northernmost fundamental geodetic research station with an array of collocated geodetic observing systems: SLR, GPS and GLONASS receivers, a superconducting gravimeter and an absolute gravimeter, geodetic VLBI and a DORIS beacon. However, Metsähovi SLR-station has been offline since the end of 2005 when the old laser built by late Dr. Paunonen begun to be too hard to maintain operational. Large efforts have been made to get our SLR system functional again with updated gear. We are now presenting the already made updates and the future plans for the telescope system. A new 2 kHz laser was purchased in 2006 to replace the obsolete 1 Hz laser. After this other major renovations were planned to improve the whole system. Upgrading of the telescope started in 2007 when new motors and encoders were decided to be mounted on the telescope. It came also evident that the optical layout of the old system would not be optimal for the new high repetition rate laser. A fundamentally different optical solution was planned together with the original designers of the telescope at the University of Latvia in Riga. The old Cassegrain-Mangin system had the laser beam travelling both ways in the same channel through the main aperture and the focus, i.e., the detector, was in a separate room. In the new system the focus of the telescope will be moved to inside of the telescope with a focal reducer designed in Riga. Besides the new focus the transmitting beam is moved to outside of the telescope into a separate beam expander. Separating the transmitting and receiving laser channels is essential for high repetition rate laser. As a side effect the focal reducer will slightly reduce the effective aperture of our 1 m main aperture. The main mirror was recoated in 2009 and the secondary mirror will be recoated in spring 2011. The mounts for the focal reducer have been made this winter in Riga and tests are under way. The aim is to install the new optical system in 2011. The old step motors of the telescope will be replaced with servo motors and the old optical glass encoders will be replaced with electronic absolute encoders with an absolute positional accuracy of ~2”. These updates will improve the speed of the telescope as well as the absolute pointing accuracy. In summer 2010 Heidenhein ERA8480C encoder was installed in the azimuth plane of the telescope. Installing of the encoder ring required careful grinding of the mount of the telescope to ensure the precise fit of the encoder. Also the azimuth rail on the mount on which the telescope rotates was levelled. The rail had height anomalies with maximum amplitude of approximately 200 micrometers. These will have to be taken account in the pointing models of the telescope. Test drives with new motors will start next summer to properly adjust and model the motors and encoder readings. In addition to the above mentioned new parts all the old parts have been repaired or replaced as the telescope has been in bits and pieces. The telescope has been repainted to minimize thermal effects as well as to prevent the old paint to peel off on the optical surfaces.

A. Maier, S. Krauss, W. Hausleitner, O. Baur
SLR providing low-degree gravity field coefficients for the new combined gravity field model GOCO02S

Combined gravity field models benefit from the integration of complementary data sets with respect to measurement type, accuracy, data coverage, etc. A new global gravity field model is to be computed by combining recent GOCE observations with GRACE, CHAMP, SLR, altimetric and terrestrial data sets. In this framework, the Space Research Institute is responsible for the determination of low-degree spherical

harmonic coefficients of the gravity field by means of SLR measurements. We conducted a series of closed-loop simulation studies to demonstrate up to which degree and order the gravity field can be resolved by SLR data analysis. In this context, we performed sensitivity studies on the number of recovered coefficients, data periods and combinations of range measurements to several geodetic satellites. The studies are based on five years (2006 to 2010) of simulated SLR measurements to LAGEOS 1 and 2, Ajisai, Stella and Starlette. With regard to real data analysis, the five-year period was sub-divided into monthly arcs in order to be able to detect temporal variations. Our simulation studies show that SLR data is particularly sensitive to the C20 term. The higher the number of estimated coefficients, the more rank-deficient becomes the normal equation system. Thus, for real data processing a maximum degree and order of five has been decided on. The same time span and satellites as chosen for the simulation experiments have been used for gravity field recovery from real data. For each month, the normal equations of all satellites were combined yielding global parameters such as station coordinates and gravity field parameters. As the feasibility studies already indicated, the contribution of SLR data to a combined high-resolution gravity field model is indeed limited to the degree-2 coefficients. As far as the estimated C20 term is concerned, a secular trend rate of -1.8e-11/year was determined.

K.Lapushka, M.Abele, K.Salminsh

SLR telescope upgrade at Riga station

This paper reports on the currently going modernization of SLR telescope at Riga. The main purpose of the upgrade is to separate transmitting and receiving channels to enable the use of the high frequency laser and to improve receiver channel efficiency. Another expected gain is an improved visual tracking capability and better calibration stability and accuracy.

Jan Kodet, Ivan Prochazka, Josef Blazej, Jan Brinek

Development and construction of the photon counting receiver for the European laser time transfer space mission

We are presenting the work progress and recent results in the development and construction of the photon counting receiver, which is prepared for the European Laser Timing (ELT) experiment in space. ELT is an optical link prepared in the frame of the ESA mission "Atomic Clock Ensemble in Space" (ACES). The ultra short laser pulses will be used to synchronize the time scales ground to space with picosecond precision. To minimize the timing biases the photon counting concept of the space born receiver was selected. The requirements put on the photon counting receiver are quite challenging in terms of the long term detection delay stability, wide operation temperature range, extremely high background photon flux and others. Recently, the bread board version of the detector has been constructed and is under extensive test in our labs. The concept and construction will be presented along with the achieved device parameters.

Hiroo Kunimori and Miho Fujieda (NICT)

T2L2 calibration using two SLR stations in Koganei re-commissioning KSP system

A Keystone (KSP) SLR system with 75cm telescope in enclosed dome in Koganei (7328) had been in operation 1997-2000 and ceased in February 2000. It located a hundred meters from existing Koganei (7308) also called Tokyo with 1.5m telescope. Since 2009 we have been gradually bringing up KSP 75cm system till summer time in 2010 and finally got LEO satellites July 2010. The system has not surprisingly, less laser power, less precision and less stability on mechanical dome than those in ten years ago due to aging parts. Nevertheless a couple of tens Lageos passes obtained by the end of December2010 which input to quality control process, station was qualified as reported by ILRS in January 2011. The station clock is derived by UTC(NICT) via optical fiber and is selectable also GPS and/or H-Maser available. Using two stations of the same UTC(NICT) standard signal configuration, we obtained the satellite (self-)ranging as well as cross ranging data at the same time because reflected beam from each station covers both stations. Using self- and cross- ranging data, calibration of T2L2 experiment is performed using LEO satellites, such as Jason2, AJISAI. The system can operate via network and an operator control two systems in the same location except system initialization and shutdown.

S. Dell'Agnello, G. O. Delle Monache, D. G. Currie, R. Vittori, C. Cantone, M. Garattini, A. Boni, M. Martini, C. Lops, N. Intaglietta, D. A. Arnold, M. R. Pearlman, G. Bianco et al

SCF-Test of Flight-quality Coated and Uncoated Cube Corner Laser Retroreflectors

Using dedicated facilities of INFN-LNF in Frascati, Italy, including the "Satellite/lunar laser ranging Characterization Facility" (SCF, [1]) we characterized the detailed thermal behavior and/or the optical

performance of many flight units of coated and uncoated cube corner laser retroreflectors. As a reference for the ILRS user community, with this poster we provide a compilation of the many tests carried out in the last years, which are not reported in the oral contributions to the 2011 laser workshop. Corresponding author: Simone Dell'Agnello, E-mail: Simone.DellAgnello@lnf.infn.it, Phone: +39-06-94032730, Fax: +39-06-94032475 [1] Dell'Agnello, S., et al, Creation of the new industry-standard space test of laser retroreflectors for he GNSS, Adv. in Space Res. 47 (2011), 822-842.

Artemov I.V., Dmytroysa A.I., Neyachenko D.I.,
Software and operational status of Simeiz SLR station.

Last years at our station some software and hardware components have been improved. These changes give us some improvements in work. But old laser doesn't allow take more significant results.

Ludwig Combrinck, Roelf Botha, Tamsen Emmerich, Francis Pierron
Progress with the development of a Satellite and Lunar Laser Ranger for South Africa

In collaboration with the Observatoire de la Côte d'Azur (France) the Hartebeesthoek Radio Astronomy Observatory (HartRAO) has commenced development of a Satellite and Lunar Laser Ranger based on an ex OCA 1 m optical telescope. We present a progress report based on recent developments and sketch planned, as well as posible equipment and software scenarios. Station layout is described and we conclude with a discussion of the site where permanent installation is planned.

V.L. Moshkov,V.D. Shargorodsky, A.P. Popov, Yu.L.Korzinin, A.V. Veniaminov
Narrowband holographic selectors for SLR – extended lifetime,

A set of serial-production narrowband holographic selectors operating at SHG of YAG:Nd+3 (532 nm) was discussed before. Main mechanisms limiting the selector lifetime are determined, and ways for increasing the lifetime and stability are shown.
New developments in satellite laser ranging at 1064 nm require extension of the selector range to the near infrared. Hologram registration technology based on the application of UV He-Cd laser radiation in the photorefractive glass material is presented in the report. A new selector operating at 1064 nm with 0.2nm s spectral selectivity and about 80% diffraction efficiency has been developed and tested.

Andrew C. Nicholas, Marc A. Davis, Scott A. Budzien, Ted T. Finne and Liam Healy
Thermospheric Density Fluctuations Derived from the Atmospheric Neutral Density Experiment Missions

The Atmospheric Neutral Density Experiment (ANDE) flights consists of four spherical microsatellites launched in pairs in 2006 (ANDERR) and in 2009 (ANDE2). The primary scientific objectives of the ANDE flight is to monitor total neutral density along the orbit for improved orbit determination of resident space objects. The missions consisted of two spherical spacecraft fitted with retro-reflectors for satellite laser ranging (SLR). Each spacecraft contained a small lightweight payload designed to determine the spin rate and orientation of the spacecraft from on-orbit measurements and from ground based observations. The laser ranging data was combined with the radar observations and processed to generate SLR augmented orbit determinations. Thermospheric density fluctuations were then derived from these orbit determinations. This paper presents the observed thermospheric density fluctuations spanning the time period from 2006 to 2010. A comparison of these data with thermospheric models, solar and geomagnetic drivers as well as other neutral density measuring techniques is presented.

Martin Ettl, Manfred Schneider, Urs Hugentobler
Solving ordinary differential equations with multi-precision libraries

Modern earth observation techniques require a precise knowledge about the position and velocity of observed satellites or other objects in space. Computing the position analytically does not provide the needed accuracy anymore, due to a missing analytical high accurate orbital-theory. In order to gain accuracy, it is common to compute an orbit by solving ordinary differential equations (ODEs). Solving this kind of mathematical equations leads to well tested standard-methods like Runge-Kutta-methods, Burlisch-Stoer, symplectic or power-series integrators. These solvers have been implemented using C++-templates allowing to change the floating-point data type at compile time. Therefore multi-precision data types with a free-to-choose decimal precision can be used. Based on this approach, each numerical solver can operate

with variable internal precision. This, for instance, makes it possible to reveal round-off errors or missing accuracies by simply increase the precision of the underlying data type. It can be used to verify computed or measured results with, so far not available numerical accuracy. Solving an ODE with high accuracy using a multi-precision library requires more CPU-cycles. This is why the implemented algorithms has been profiled and highly optimized to avoid wasting CPU-cycles on our testing platforms.

Georg Kirchner, Franz Koidl, Daniel Kucharski

Using Pulse Position Modulation in SLR stations to transmit data to satellites

At the Graz 2 kHz SLR station, we upgraded the software to modulate the – usually constant – interval between successive laser pulses using such a Pulse Position Modulation (PPM) scheme, we successfully transmitted text files via a 4288 m distant CCR back to a Multi-Pixel Photon Counting (MPPC) module in our receiver telescope. With such a setup at any SLR station, and a suitable detector plus simple time tagging electronics at Low Earth Orbiting (LEO < 1000 km) satellites, it is possible for any kHz SLR station to transmit data to satellites with a rate of up to 2 kBytes/s - even during standard SLR tracking.
As this technique is easy to implement and does not affect routine kHz SLR tracking, it can be applied to upload data to satellites, using the more than 30 available SLR stations around the world, and with higher data rates than some of the conventional microwave uplinks.