Section 8
Working Group Reports

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WORKING GROUP REPORTS

The ILRS Governing Board established several permanent (Standing) or temporary (Ad-Hoc) Working Groups to carry out the business of the ILRS. . Standing Working Groups carry out continuously evolving business of the ILRS. Ad-Hoc Working Groups are appointed to work special investigations or tasks of a temporary nature. Currently, the ILRS has five standing Working Groups: Analysis, Data Formats and Procedures, Missions, Networks and Engineering, and Transponder. The Working Groups are intended to provide the expertise to make technical decisions and to plan programmatic courses of action and are responsible for reviewing and approving the content of technical and scientific databases maintained by the Central Bureau.

ANALYSIS WORKING GROUP (AWG)

Erricos C. Pavlis/Goddard Earth Science and Technology Center, Cinzia Luceri/e-GEOS, Centro di Geodesia Spaziale "G. Colombo"

Official ILRS Analysis Products

The main activity of the Analysis Working Group during the 2009 - 2010 period was the routine generation of the official daily and weekly products. With the development of ITRF2008 in progress, the AWG planned and executed a complete reanalysis of ILRS data used for ITRF2008 and covering the period 1983 to early 2009. The ILRS contribution was submitted in mid-2009. Following the release of the candidate ITRF2008 solutions the AWG evaluated them during the designated period prior to the final acceptance in October 2010.

Pilot Projects

The AWG approach to the development of new products includes the execution of Pilot Projects (PP) during which the new products are tested and the ACs refine their processing and operational approach. The first step in most cases is the harmonization of the capabilities of all AC software to bring them to the same state of readiness for the execution of the planned PP.

During the 2009-2010 period, the Orbital Product PP was initiated and the ACs initiated software upgrade work required for the implementation of the new site and time dependent CoM corrections for the LAGEOS and Etalon satellites. The delivery of additional future products which also require the extension of the standard capabilities for some of the utilized software was discussed and various ACs initiated the required work to be able to eventually deliver low degree harmonic estimates along with the "pos+eop" product, as well as the incorporation of advanced modeling of time-varying gravity signals due atmospheric circulation, atmospheric loading at the tracking sites, etc.

Validation of CRD Format Implementation

The newly developed CRD format will soon replace the old "CSTG" format for increased precision, data characterization and quality control. Before the actual adoption of the new format, the ILRS decided on a strict validation of the newly implemented format for each station of the network. The role of the AWG in the process is to assure that the same data delivered by each station in both formats describe exactly the same orbit for the target. Once the new format implementation was checked by the Operational Centers for any syntax errors, the next step was the validation of data by the AWG. Several ACs checked the format compliance and then insured that there were no systematic differences between the data in the two formats. Once the entire network is validated the ILRS will adopt the new format and the use of the CSTG format will be discontinued. In anticipation of this change, the AWG underwent a test-run using the new format to ensure that each of the ACs is ready to use the new format.

AWG Meetings

The AWG tries to meet at a minimum twice a year, typically one meeting associated with the EGU meeting in the spring, and a second meeting, usually in the summer, autumn or fall, associated with either an ILRS International Laser Workshop, an ILRS Technical Workshop or some other meeting where a large number of ILRS Analysts are likely to participate. The 22nd AWG meeting was held April 24, from 09:00-18:00, at the EGU meeting in Vienna, Austria. The brief, half-day 23rd meeting followed at the end of the Fall ILRS Technical Workshop in Metsovo, Greece, on September 19, 2009. In 2010, the 24th AWG meeting was held on May 8 during the EGU meeting in Vienna, Austria. The 25th and final AWG meeting for this period was held on October 1 in Paris, France. Several members of the AWG participated with presentations and contributions to several position papers in the Unified Analysis Workshop of the Global Geodetic Observing System (GGOS), in December 2009, in San Francisco, CA.

Other Activities

The AWG is also responsible for the re-certification of stations that return to operations after a lengthy down time or a major upgrade. Similarly, when new stations are applying for acceptance into the ILRS network, the AWG is responsible for the validation of their data quality and the characterization of their performance. The 2009-2010 period saw several of both cases, when sites returned to operations after earthquake events, major upgrades or simply new sites joined the ILRS.

Other activities of the AGWG include the evaluation of new models for various components of the dynamical and measurement models used in the reduction of the data, the adaptation of new standards as directed by the IERS, and the support of the organization of ILRS meetings.

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DATA FORMATS AND PROCEDURES WORKING GROUP (DFPWG)

Randy Ricklefs/CSR

The Working Group's major activities during 2009 and 2010 were implementing the new Consolidated laser Ranging Data format (CRD), surveying the ILRS stations regarding implementation of satellite tracking restrictions, and several data handling issues. Unfortunately, at the end of this period, the Chairman of the Working Group, Wolfgang Seemueller passed away after an extended illness.

CRD Format Implementation

The CRD format was developed to provide a way to capture higher precision, higher volume, and better documented data than the old "CSTG" format. Validation of data in the new format from each of the stations was an important issue, with the Operations Centers (OCs), Analysis Working Group (AWG), and several ILRS Analysis centers (ACs) performing this service. Validation consists of checking for format compliance and then insuring that there are no systematic differences between data in the old and new format for each station. At the beginning of the period, only 1 station was validated; at the end there were 25.

Restricted Tracking

It has become important for laser ranging stations to handle restrictions placed on satellite tracking by their mission operators, generally with the purpose of preventing damage to on-board sensors. Because of several missions, there have been requirements for a maximum tracking elevation, tracking only certain segments of a pass, or suspending tracking for sustained periods (through the so-called go/no-go files). During this period, yet another restriction, on power delivered to the satellite, was added due to Lunar Reconnaissance Orbiter (LRO) requirements. Although a certain subset of stations is used to track these missions, it is important that the ILRS know which stations are ready to help with these special missions. To this end, a survey was conducted of stations and their implementation of the restrictions. The results are on the ILRS website.

Other Activities

Several issues have dealt with the ILRS Operations and Data Centers. When a new laser ranging station opens, or an existing station undergoes upgrades or is simply off-line for many months, the station's data must be quarantined until the Analysis Working Group has insured there are no unexpected changes or biases in the data. Making the quarantine process more systematic and automated has progressed during this period. With the new CRD format, there has been an effort to insure that both the EDC and NASA Operations Centers use similar data quality checking. Similarly, it has been a goal to make the data directories the same on the EDC and NASA Data Centers for the new format, to ease data users' access and minimize confusion.

Much of the Working Group's effort, from implementing the CRD format, surveying tracking restrictions, and handling data issues are all works in progress, and all have involved the tireless support of the members, the ILRS Central Bureau, the Operations Centers, the Data Centers, and the Analysis Working Group.

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MISSIONS WORKING GROUP (MWG)

Graham Appleby/SGF

Introduction

The ILRS Missions Working Group (MWG) is tasked with managing and carrying out the review of new missions that seek laser ranging support from the ILRS. The MWG membership comprises some twenty ILRS associates who represent a wide spectrum of technical, scientific and tracking network expertise. The chairs of the Analysis, Network and Engineering, Signal Processing, and Data Formats and Procedures Working Groups are ex-officio members of the MWG, as are representatives from the NASA, WPLTN, and Eurolas tracking sub-networks, and from the ILRS Central Bureau (CB).

New Mission Support

Ideally at least a year ahead of launch, the mission will download the Mission Support Request form from the ILRS website at *http://ilrs.gsfc.nasa.gov/docs/2011/ilrsmsr_1106.pdf* and, once completed, submit it to the CB. The chair and co-chair of the MWG then circulate it, if necessary with some accompanying explanation and a deadline for responses, to the MWG membership. A full email-discussion of the mission request is encouraged, with a view to understanding the mission-specific need for very precise tracking, the nature of perhaps intensive tracking campaigns and whether or not the mission has made adequate provision for the protection from laser light of any onboard sensitive detectors. Also very important to document before launch is a full description of the physical characteristics of the retro-reflector array and its 3D location on the satellite; metric information not recorded before launch is unlikely to be determinable afterwards. Once the MWG members have come to a decision on the suitability of the mission for ILRS support, often after some specific issues have been raised with the mission, a recommendation is made to the ILRS Governing Board (GB). The CB then deals directly with the mission to ensure that predictions will be made available on a daily basis to the stations and that, for instance, any go/no-go issues are dealt with.

During the reporting period three new missions (as detailed in Section 4) were reviewed by the MWG. RadioAstron is a very ambitious astrophysics and relativity mission that takes the VLBI technique into space with a satellite in a highly-elliptical orbit of perigee 500km and apogee at a lunar distance of 350,000km. KOMPSAT-5 is a LEO SAR Earth-observation mission and SARAL is a LEO oceanography mission. The MWG recommended to the ILRS GB that in each of these cases tracking and data-handling support should be given.

Meetings

Given the nature of the tasks of the MWG, email is the most appropriate communication forum to deal with new support requests, and the willingness of the membership to engage in the review process is key to the procedure and gratefully acknowledged. However, on occasion, the opportunity is taken to hold short working group meetings in conjunction with ILRS workshops or science assemblies such as the EGU or AGU. During the reporting period, an MWG meeting was held during the 2009 September ILRS Technical Workshop on SLR Tracking of GNSS Constellations in Metsovo, Greece. Discussed was the membership of the MWG and it was agreed that the chairs of the other ILRS Working Groups should contribute to the evaluation process, consulting their members if appropriate. Future such opportunities for short meetings will be taken as they arise.

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NETWORKS AND ENGINEERING WORKING GROUP (NEWG)

Georg Kirchner/Austrian Academy of Sciences

Laser Beam Divergence Determination in SLR Stations

Especially with regard to calculations of energy density on the satellite (detector safety) and retro reflector link calculations, the knowledge of actual laser beam divergence becomes more important; to get at least some basic idea, the stations were asked to describe their methods and procedures to determine this value. Conclusion/Summary:

None of the SLR systems really measures the actual (far field) laser divergence (in the sense of getting a number); all systems apply some method rather to minimize the laser beam divergence (which is obviously the basic requirement for an SLR station).

In monostatic systems, usually 2 CCR on the spider of the secondary mirror are used to adjust for minimum divergence; bistatic systems are minimizing divergence - in a less scientific approach - by offset pointing to HEO satellites and correlating it with return rates (works okay to adjust for minimum divergence, gives at least a rough idea of the number); and by observing backscatter images of the laser beam. Measuring diameters of laser beam at a few km distances is not really suitable to get correct values (no far field). Nobody is using some of the standard methods (e.g., *http://www.uslasercorp.com/envoy/diverge.html).*

There have been suggestions to measure laser beam divergence via the onboard device of T2L2; however, this would include atmospheric seeing influence, thus limiting the accuracy to at least the actual seeing values; might work for stations with acceptable seeing values.

Other main activities of the NEWG included assisting existing (China) and new stations (Korea, Metsahövi) in design, technique, hardware/software, operational issues etc; especially close cooperation was with Korea: A new transportable SLR station has been built by KASI, and should start with first tests at the end of 2011; several visits by the Korean contacts at Graz and other SLR stations (from few weeks to few months each); tests/verification of calibration circuits, etc. were very helpful.

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SIGNAL PROCESSING WORKING GROUP (SPWG)

Toshimichi Otsubo /Hitotsubashi University

Introduction

Retroreflector array is the prime component in the space segment of satellite laser ranging technique, and is the prime subject of research for the ILRS Signal Processing Working Group. It was organized in 1999 originally for studying the measurement accuracy degradation due to the pulse-spread effect of return signal. This group has been tightly linked with other working groups, and it has extended the study coverage in these years as described below.

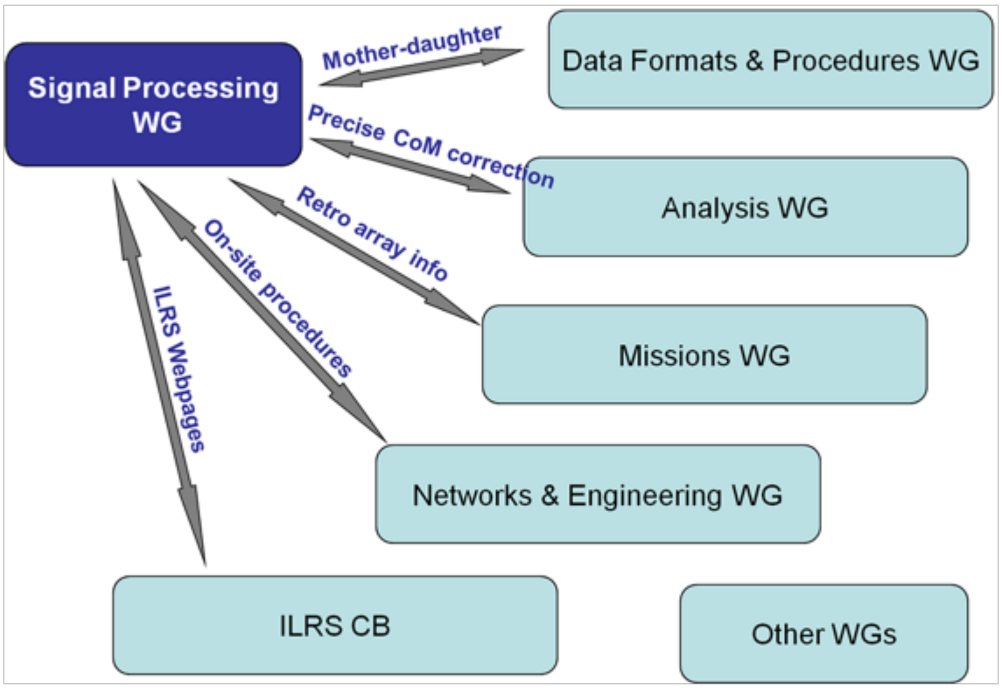

Figure 8-1. SPWG process.

System-Dependent and Intensity-Dependent Center-of-Mass Correction

SLR measurements ideally deliver the absolute two-way measurement between the ground station and the centre-of-mass (CoM) of the satellite. However, an intensity dependence has been proposed and detected in the actual laser ranging data. The post-fit residual data were sorted by the number of single-shot returns per normal point bin, which should be strongly related with the signal intensity reaching the detector. If the detection signal intensity varies, and if the detection timing is dependent on it, there will be intensity dependent bias. The so-called target signature effect, which is now the major error source of laser ranging technique, can reach 4 to 5 cm for Ajisai and 1 cm for LAGEOS, and as previous target signature studies predicted, strong signals make the range measurements shorter when compared to weak return signals. This intensity-dependent effect is detected in the SLR data of a number of stations by looking into the residuals of precise orbit determination analyses. The effect for Ajisai is the largest in most cases, but a number of stations show a significant trend (mostly negative) even for LAGEOS.

A recent effort has been completed to model the station-dependent satellite signature effect for the LAGEOS and Etalon satellites. The previously-published (Otsubo and Appleby, JGR, 2003) results on CoM corrections as a function of detection system, processing technique and return signal strength were used to determine a range of possible CoM corrections for each tracking station that has been active since the early 1980s. The ILRS station log files were used to determine date-dependent station hardware and software configurations, and a table of appropriate CoM corrections was developed. In many cases, such as when the log files indicate that the station does not control the return rate, the range of possible CoM values is large, perhaps up to 10mm, but it is felt that, on average, a better representation of the true CoM correction is being made when these results are implemented. It is anticipated that this work will be extended to include Ajisai and Starlette/Stella.

Laboratory Simulation of Thermal Behavior of Retroreflectors

It is important to optimize the design of the space segment to work efficiently. A ground support equipment facility to characterize retroreflectors in accurate laboratory-simulated space conditions has been developed at INFN/LNF, Italy, which is called "Satellite/lunar laser ranging Characterization Facility" (SCF). It can measure the optical far field diffraction pattern (FFDP) and the temperature distribution of retroreflectors under realistic thermal control and attitude conditions of retroreflectors in orbit, illuminated by high-fidelity a solar simulator. Infrared cameras are also equipped to monitor the thermal response. The retroreflectors for future GNSS satellites and LAGEOS engineering model has been actually examined using this facility, and the measured FFDP results were compared with computer-simulated FFDP. This so-called SCF-Test is described in detail in Dell'Agnello, et al., Adv. Space Res., 2011.

Determination of Spin Parameters and Orientation-Dependent Center-of-Mass Correction

One of "spin-off" studies utilizing the target signature effect is the determination of spin parameter of laser ranging targets. The complicated arrangement of the Ajisai retroreflectors and the kHz laser ranging observations has made it possible to determine its spin axis orientation as well as its spin rate. The precise spin parameter determination reveals that the spin parameters of Ajisai vary secularly and periodically, and that the periodical component is correlated with its orbital plane with respect to the sun.

The retroreflector arrays carried on Envisat, ERS-2, GRACE-A, and -B, had been recognized as signature-free targets, but a kHz data residual analysis shows clear variations up to 5 mm. This fact suggests their CoM corrections should be modeled to be dependent on their orientation parameters in an orbit analysis stage. In addition, in order to improve the ranging precision with the future satellites, this working group will also strive to minimize or zeorise the target signature effect, together with Missions Working Group.

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TRANSPONDER WORKING GROUP (TWG)

Ulrich Schreiber/TU Munich

Activities within the Transponder Working Group (TWG) for 2009-2010 are summarized below.

Lunar Reconnaissance Orbiter Laser Ranging (LRO-LR)

Jan McGarry/NASA GSFC, John Degnan/Sigma Space, Inc.

The Lunar Reconnaissance Orbiter (LRO) spacecraft was launched in June 2009, and is currently in a 50 km lunar orbit above the Moon. A move to an elliptical 200 km x 30 km orbit is expected in late 2011, and the mission is expected to continue at least through 2012. Among the instruments is the Lunar Orbiter Laser Altimeter (LOLA), which uses 5 laser altimetry channels to map the lunar surface. A Diffractive Optical element (DOE) is used to generate 5 laser beamlets from a single transmitter firing at 28 Hz. One of the altimeter channels does double-duty as a receiver for the altimeter beam and to detect laser pulses from Earth. The science goals of the Earth-based Laser Ranging (LR) experiments include a more precise orbit determination than can be acquired from the available microwave tracking and an improved lunar gravity field. The LR signals are collected by a one-inch aperture telescope mounted on the S-band microwave tracking and communications antenna and transferred by fiber optics to the LOLA receiver. In order to be seen and recorded by LOLA, the Earth based pulses must arrive within an 8 msec period within the roughly 36 msec period between laser pulses. Unlike two-way laser transponders, the success of this one-way technique requires continuous synchronization of the ground-based and spaceborne clocks. LRO-LR represents the first operational use of laser ranging to a satellite in orbit about an extraterrestrial body, and, as of the 17th International Workshop on Laser Ranging in May 2011, over 1070 hours of laser ranging (LR) data had been obtained from 10 participating ILRS stations. Occasional simultaneous LR data from multiple ILRS stations is also being used to obtain geometric spacecraft position solutions. A low data rate lasercom demonstration spelling out “LRO-LR” in the Observed Minus Calculated (OMC) range data was presented, and plans for other lasercom and global time transfer experiments are in progress.

Time Transfer by Laser Link (T2L2)

Etienne Samain, Jean-Marie Torre/OCA

T2L2 (Time Transfer by Laser Link), developed by both CNES and OCA permits the synchronization of remote ultra-stable clocks over intercontinental distances. The principle is derived from laser telemetry technology with dedicated space equipment deigned to record the arrival times of laser pulses at the satellite. Using laser pulses instead of radio frequency signals, T2L2 provides laser links between distant clocks allowing time transfer with a stability of a few picoseconds and accuracy better than 100 ps.

The T2L2 space instrument on board the satellite Jason 2 has been in operation since June 2008. After a six-month period devoted to the characterization and the calibration of the system, the mission has been operational since January 2009. Several campaigns were done to demonstrate both the ultimate time accuracy and time stability capabilities. The main results of these campaigns are:

- Time accuracy in collocation: better than 50 ps
- Phase carrier GPS – T2L2 comparison: limited by the GPS noise
- Ground – space time transfer stability: better than 10 ps @ 10 s

Some important work has been done to accurately compare T2L2 with microwave time transfer GPS and Two-Way Satellite Time and Frequency Transfer (TWSTFT). These comparisons are based on laser station calibrations with a dedicated T2L2 calibration station designed to accurately set the optical reference of the laser station within the pulse per second (PPS) reference of the time and frequency laboratory.

European Laser Time Transfer Experiment (ELT)

Ulrich Schreiber/TU Munich, Ivan Prochazka/TU Prague, Anja Schlicht, Pierre Lauber/TU Munich

The European Laser Time Transfer Experiment (ELT) was proposed to support the (Atomic Clock Ensemble in Space (ACES) Mission, which aims at operating high precision atomic clocks in a micro-g environment. The objective of this proposal is to augment the two-way microwave time and frequency transfer with an optical counterpart. In order to reduce the requirements on the space segment hardware, the microwave link and the laser time transfer link share essential parts of the event timing hardware. The ELT space segment consists of a corner cube assembly similar to the design used for the Champ satellite and an avalanche photodiode detector in Geiger mode (SPAD). Therefore the ranging measurements support the time transfer mission with both two-way and one-way ranging. The proposal was accepted by ESA and is currently under development. The Engineering Model of the space segment detector is under construction and evaluation in the Czech Republic. The ELT data center is under development at the Technical University of Munich in Germany. A call for participation and the application of mission support for the Missions Working Group is in preparation.

Gravity, Einstein's Theory, and Exploration of the Martian Moons' Environment (GETEMME)

Juergen Oberst/DLR, Ulrich Schreiber/TU Munich

This mission proposal was submitted to the ESA Cosmic Vision Program with a proposed launch date of 2020 or 2021. The objectives of the mission were to use laser transponder technology to study the dynamic parameters of the Mars satellite system (satellite orbit and rotation models) and to improve the accuracy of key Fundamental Physics parameters, such as the Post-Newtonian beta-parameter, time-rate changes in the Gravitational constant G, and the Lense-Thirring effect. This can be achieved by ranging to the Martian moons Phobos and Deimos from a Mars orbit. At the same time, two-way asynchronous transponder techniques between Earth and Mars can be used to improve the orbit estimations of the Mars orbiter. A number of preliminary studies were carried out in support of this proposal. At this stage, the mission proposal has not been accepted.

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