ILRS Governing Board

Chancellor Hotel
San Francisco, CA USA

December 14, 2009
07:00-09:30 p.m.
Agenda

1. Opening Remarks (5 min.)  M. Pearlman
2. Remarks by the New Chair  G. Appleby
3. ILRS Status/Central Bureau Report (20 min.)  M. Pearlman/C. Noll
4. WG Briefs and Recommendations (5-10 min each)
   - Analysis (including status of data products)  E. Pavlis/C. Luceri
   - Missions (new missions/new missions approved/challenges)  G. Appleby
   - Data Formats and Procedures  C. Noll for W. Seemueller
   - Networks and Engineering (Stanford Counters, etc.)  G. Appleby
   - Transponders (incl. LRO)  J. McGarry
   - Lunar Laser Ranging  J. Mueller
5. Task Force Reports (5 min. each)  M. Torrence
   - Communications  G. Appleby
   - Center-of-Mass Corrections  M. Pearlman
6. Normal Point Formulation (10 min)  M. Pearlman
7. Status of the ITRF 2008 (10 min)  Z. Altamimi
8. Report on the Metsovo Meeting (10 min)  E. Pavlis
9. Retroreflector Issues (10 min)  M. Pearlman/G. Appleby
10. ILRS Special Issue in Journal of Geodesy (5 min.)  E. Pavlis
11. GGOS Activities (5 min.)  M. Pearlman
12. New Business
13. Other Business

All presentations will be posted on the ILRS website; please be concise
Coffee, tea, cold drinks, and cookies will be served
ILRS Governing Board 2008-2010

Director of the Central Bureau: Mike Pearlman (appointed)
Secretary of the Central Bureau: Carey Noll (appointed)
President of IAG Commission 1: Zuheir Altamimi (appointed)
IERS Representative: Bob Schutz (appointed)
EUROLAS Network Representatives: Giuseppe Bianco, Francis Pierron
NASA Network Representatives: David Carter, Jan McGarry
WPLTN Network Representatives: Yang Fumin, Ramesh Govind
Data Center Representative: Wolfgang Seemueller
LLR Representatives: Juergen Mueller
Analysis Representatives: Cinzia Luceri, Erricos Pavlis
At-Large Representatives: Graham Appleby*, Georg Kirchner

* Newly elected chair for 2010
ILRS Working Groups

- Analysis
  - E. Pavlis/C. Luceri
- Missions
  - G. Appleby/S. Wetzel
- Data Formats and Procedures
  - W. Seemueller/R. Ricklefs
- Networks and Engineering
  - G. Kirchner/U. Schreiber
- Transponder
  - U. Schreiber/J. McGarry
Central Bureau Update
Network Status

- 38 stations providing tracking data in 2009
- Most productive stations are Yarragadee, Zimmerwald, Mt. Stromlo, Greenbelt, Changchun, Wettzell, San Juan, Graz, San Fernando, and Herstmonceux
- All MOBLAS systems (except Tahiti) and MLRS operating at 10Hz on low satellites
- Tahiti operational after visit by HTSI engineer; data under evaluation
- Arequipa not operational due to MCP failure
- Wettzell not operational due to mechanical issues with the telescope drive; staff hopes to bring new system (SOS-W) online shortly
- APOLLO lunar system to participate in LRO-LR and two-way ranging experiments in early 2010; need to resolve data transmission plans
Annual Data Yield

**Note:** *statistics through 11/30/2009*
Station Performance
All Satellites (2009Q3)

Note: *Mobile occupation

Total ILRS pass performance standard is 1500 passes
Station Performance
Minutes of Data (2009Q3)

Note: *Mobile occupation
Mission Developments

- Currently supporting 27 missions and lunar tracking
- SOHLA-1 campaign in March, second campaign in fall possible
- GOCE tracking has improved mainly due to predictions generated by CODE from GNSS data
- STSAT-1 launch failure in April 2009

Recent launches:
- LRO: 30-Jun-2009
- ANDE: 30-Jul-2009
- Blits: 17-Sep-2009

Upcoming launches of approved missions:
- Proba-2 (ESA): 02-Nov-2009 (tracking in Jan-2010)
- CryoSat-2 (ESA): 28-Feb-2010
- RadioAstron (Russia): Dec-2009 (tracking by lunar-capable stations)
- STSAT-2B (KARI): May-2010
- TanDEM-X (DLR, GFZ, others): 2009?
- QZS-1 (JAXA): 2009?

Three new GLONASS satellites launched on December 14.
Yearly Pass Totals
Asia

Note: *statistics through 11/30/2009
Yearly Pass Totals
Europe

Note: *statistics through 11/30/2009
Yearly Pass Totals
North America

Note: *statistics through 11/30/2009
Yearly Pass Totals
Southern Hemisphere

Note: *statistics through 11/30/2009
Restricted Tracking

- Survey of stations distributed; 31 responses received
- 4 other productive stations have been queried repeatedly w/o response: Katzively (invalid email address), Changchun, Shanghai, and Riyadh
- Results (based on 31 responses):

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CRD Format Development

- CRD testing performed in phases:
  - Station submits CRD to OCs (HTSI and EDC)
  - OCs perform format validation and new/old normal point comparison and verification
  - HTSI to perform test orbit validation with prediction orbit
  - ACs perform precise orbit validation
  - Station submits only CRD after validation (OCs convert to ILRS NPT format until completion)
- Current status:
  - 5 stations operational: MLRS, Zimmerwald, Herstmonceux, Matera, Wettzell
  - 7 stations have completed coding and OC validation; under review with ACs
  - 4 stations have completed coding and have submitted data for OC validation
  - 8 stations currently coding to generate CRD
  - 19 stations have not responded to inquiries; reminder sent
- Goal of January 2010 conversion needs to be extended
- Hourly distribution of CRD normal points converted to CSTG format is not yet occurring at EDC; 4 operational stations still send both old and new format
- CRD errata have been rolled into v1.01 of the CRD manual and sample code on ILRS website
Other CB Items

- Criteria for certification of new stations and requalification of stations after upgrading or significant downtime still needs to be addressed
- Simplified algorithm to encourage stations to better distribute tracking efforts perhaps using the real-time web facility at AIUB needs to be developed
- Stations contacted and encouraged to submit full-rate data; data centers will be able to accommodate full-rate data from kHz stations
- CDDIS and EDC data center structures supporting CRD-formatted data will be harmonized
- ILRS 2007-2008 Report now in final preparation
- Proceedings from 16th International Laser Ranging Workshop to be printed this month
- Website for both the 16th International Laser Ranging Workshop and Fall ILRS Workshop in Metsovo implemented
NGSLR Developments

- Still working to produce good system performance with ground calibrations that are stable to better than 1 centimeter over hour period. Not sure why this is proving so hard. Tom Varghese and Tom Zagwodzki are working this with John Degnan consulting.

- In parallel with above work (and with LRO-LR at NGSLR) we are working the completion of the automation and documenting the system.
LRO-LR Developments

• Have over 120 hours of successful laser ranging data to LRO.
• Seven stations have successfully ranged: NGSLR, MOBLAS-7, MLRS, Herstmonceux, Zimmerwald, Wettzell, and Hartebeesthoek.
• Monument Peak will start their ranging attempts next week and Yarragadee will follow shortly.
• Using LR and LOLA data the LOLA Science Team has been able to transfer time from the ground to LRO. Preliminary results suggest that using LR the LRO clock can be correlated to ground clock to at least a millisecond.
• Lots of good publicity for SLR from LRO-LR!
Meetings

- December 14-18, 2009: Fall 2009 AGU
  - GGOS Unified Analysis Workshop, Networks and Communications Bureau meetings
- May 01-07, 2010: EGU, Vienna Austria
- July 18-25, 2010: 38th COSPAR Scientific Assembly, Bremen Germany
- January 2011: 17th International Workshop on Laser Ranging, Concepción Chile
- June 28-July 7, 2011: IUGG General Assembly, Melbourne Australia
Analysis Working Group Report

ILRS Governing Board Meeting
San Francisco, CA, Monday, December 14, 2010

Erricos C. Pavlis & Cinzia Luceri
Analysis Coordinators
AWG News

• Eight AC: ASI (AC & CC), BKG, DGFI (AC & CC), GA, GFZ, GRGS, JCET, and NSGF

• Candidate AC/AAC: BKG/AIUB, ESOC, MCC and NCL

• Operational products (weekly & daily) are delivered routinely on time

• Re-analysis for 1993 to present by seven ACs: *ASI, DGFI, GA, GFZ, GRGS, JCET, NSGF*

• Historical data re-analysis 1983 to 1992 by six ACs: *ASI, DGFI, GA, GFZ, JCET, NSGF*

• Both CCs submitted combinations to ITRF2008
ILRSA solution overall quality

Core Sites - Residuals WRMS wrt SLRF2005

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ILRSA solution Reference Frame stability

Contributing Solutions

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ILRSA solution Reference Frame stability

$\Delta$ Scale

$\Delta$Scale_dot: $-0.30 \pm 0.01$ mm/yr

WRMS(residuals): 3.15 mm
AWG New Projects

- **Projects currently in progress:**
  - Orbit products (SP3C) -- 6 AC in testing (ASI, BKG, DGFI, GA, GRGS, JCET)
  - Daily solutions of 7-day arcs for 1\textsuperscript{d} EOP for NEOS (5 ACs + DGFI soon!?)
  - CRD data format station validation active ACs: ASI, DGFI, GFZ, and JCET

- **New Potential projects:**
  - Testing the application of atmospheric effects in ILRS products
  - Generation of a “low degree ~2 harmonics” series (for CPP/GGOS)
  - 3-4 ACs to study the possibility of a new definition of NP generation procedure
  - Use of Starlette and Ajisai initially for EOP and eventually for TRF products with improved modeling (e.g. atmospheric effects)
  - Near real-time analysis of SLR data for “station health”/bias Rpts.
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## Important Sites that MUST Accelerate CRD Implementation

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AWG Meetings, Past/Future

• The AWG met twice so far in 2009:
  – EGU 2009, Vienna, Austria
  – ILRS Tech. Laser Workshop, Sept. 2009, Metsovo, Greece

• Next meetings:
  – EGU 2010, TUW, Friday, May 8, 2010
  – ???
  – 17th ILRS Int. Workshop, Conception, Chile, Jan. 2011(?)
• All ACs and CCs have submitted online documentation (required by IAG/IERS/GGOS) describing the models and standards used in their routine analysis, only some AACs (*need to remind them often!*)

• A LR-dedicated special issue of the *Journal of Geodesy* to be compiled for better and wider documentation of ILRS (ground segment, space segment, data analysis and interpretation). *An initial TOC ready by Jan. 2010.*
J of G Guest EB

• J of Geodesy Editor contacted
• Procedures and limitations imposed by JoG provided (no problem)
• ILRS Special Issue Editors:
  – Pavlis, Luceri, Pearlman
• Delayed due to higher priority for the development of the ILRS contribution to ITRF2008 (will be basis for this issue)
• Realistic time-table for soliciting papers: January ‘10
ILRS Missions Working Group report to GB  
Monday December 14th 2009, San Francisco  

G Appleby, MWG coordinator
Routine procedure for support recommendations

• As well as asking MWG members for comments:

• Use expertise in other Working Groups too:
  – Analysis WG regarding need for POD
  – Signal Processing for comments on LRA suitability
  – DFPWG and NEWG regarding operational issues (go-nogo flags, available CPFs, etc)

• Chairs of these WGs are ex-officio members of MWG
Missions approved for SLR and recently launched

- **BLITS** – 17cm ball lens in Space - (IPIE) – approved. Useful discussion with IPIE regarding details of CoM correction. 2009 Sept 17 launch.
  Good predictions and tracking (on-off)

- **ANDE** (Castor & Pollux) - (NRL) – approved. 2009 July 30 launch
  Predictions of variable quality (see NEWG report)
Missions recently approved for ILRS support

- CryoSat-2 – thickness of sea-ice and elevation of ice-sheets
- DORIS tracking with laser for altimeter calibration and additional POD support
- Due for launch 2010 Feb 28 into 750km polar orbit.
- No particular tracking issues.
Missions recently approved for ILRS support (2)

• RadioAstron – 10m VLBI dish in highly-elliptical orbit (0.96, 500-350,000km)
• Visibility of (100-cube) retro-arrays from Earth expected best at distances of 100-200 thousand km;
  – Realistic target only for LLR-capable systems
• MWG liaising – Matera, Wettzell expressed interest so far;
• Launch imminent (2009 December)
Missions recently approved for ILRS support (3)

- Quasi-Zenith-Satellite, QZS-1
- Japanese GNSS system, addition to existing GNSS
- To be launched late 2010 into 45°, 32,000-40,000km orbit
- Ranging from WPLTN
GLONASS

• Three new vehicles launched 2009 Dec 14
• MWG working with CODE to recommend which one of new vehicles to track:
  – Only 1 GPS now, so go for 4 GLONASS?
• Also, discuss whether to attempt more of the GL constellation;
  – Issue is more satellites, less data or less satellites, more data on each
  – SGF Herstmonceux running a test now to attempt all GLONASS – data to be submitted to CDDIS and EDC
CRD Format Implementation

- Operational: 5 stations - MLRS, Zimmerwald, Herstmonceux, Matera, Wettzell
- In Analyst Validation: 7
- In OC Validation: 4
- In Coding: 7
- No known activity: 20; A reminder has been sent
- Goal of January 2010 conversion needs to be extended
- Hourly distribution of CRD normal points converted to CSTG format is not yet occurring at EDC; 4 operational stations still send both old and new format
- CRD errata have been rolled into v1.01 of the CRD manual and sample code on ILRS website
Data Center “Harmonization”

- Applies to CRD formatted data only

- EDC and NASA/HTSI OCs' quality control and format verification procedures are under review for consistency

- File naming conventions identical; EDC has fixed problem with “allsat” naming.

- EDC is making directory naming consistent with CDDIS

- CDDIS is making contents of daily files consistent with EDC (contains all data taken on a given day)
Tracking Restrictions Questionnaire

- 31 stations have now responded after many queries
- 4 other productive stations have been queried repeatedly w/o response: Katsively (email returns!), Changchun, Shanghai, and Riyadh.
- Results:

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<th>Restriction</th>
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Based on responses for 31 stations
Summary for June-Dec 2009

• Main work was connected with GOCE (and partially with ANDE):
  – Pushing for better predictions,
  – exchanging TB information mails,
  – pushing stations;
  – encouraging them;
  – testing methods etc.

• Tracking GOCE now is pretty standard
  – Good achievement for ILRS
Summary for June-Dec 2009 (2)

• Similarly, we tried to push BLITS and ANDE TB info exchange
• BLITS successful
• ANDE still big TB differences preds/true
  – Realtime exchange via EUROLAS good
  – But TB predictions poor sometimes:
LLR – Status Report

Jürgen Müller

Institut für Erdmessung
(Institute of Geodesy)
Leibniz Universität Hannover
(University of Hannover)
Retro-Reflectors and Observatories

- First reflector deployed on July 21, 1969 (Apollo 11)
- Continuous LLR observations for 40 years
Statistics - Reflectors and Observatories

Pie chart 1:
- Apollo 11: 9%
- Lunokhud 1: 3%
- Apollo 14: 9%
- Apollo 15: 9%
- Total: 79%

Pie chart 2:
- McDonald: 4%
- Haleakala: 2%
- Grasse: 54%
- APOLLO: 2%
- Total: 100%
Number of Normal Points

- 1970 - 2009: ca. 16,800 normal points
Main Research at Lunar Analysis Centers

- Jet Propulsion Laboratory (JPL):
  - lunar interior, lunar core
  - relativity
- Paris Observatory Lunar Analysis Center (POLAC):
  - libration theory
  - reference frames
- Institute of Geodesy (IfE):
  - Earth orientation
  - lunar interior
  - relativity
- others:
  - special topics
Status, Perspective

- McDonald will cease lunar tracking in February 2010, but LRO tracking
- APOLLO will also start LRO tracking
- Grasse with first new lunar normal points (end 2009)
- Matera plans to re-start LLR
- Wettzell plans to use old SLR system for lunar tracking …

  - first workshop: 15.-19.02.2010 in Bern
Task Forces (TF)

At the October 2007 meeting of the ILRS Governing Board, the board decided to create two Task Forces to address concerns expressed during the 2007 Fall Workshop in Grasse:

1. Inadequate two-way communication between the stations and the analysis centers to provide (a) unambiguous, timely reports to the stations regarding data quality and bias information, and (b) timely reports to the analysis centers on configuration changes and other events that could affect system biases.

   Task Force 1 was set up with Mark Torrence (lead), Ermicos Pavlis, Mike Pearman, Georg Kirchner and Werner Gurtner to provide a plan for discussion by the 2007 Fall AGU in San Francisco on how to address the communications issue. Recent activities:
   - Meeting on 10/30/2007 (notes PDF)
   - Meeting on 12/10/2007

2. Large uncertainties in the spacecraft center of mass offsets, with particular concern on the geodynamic satellites.

A task force was set up with Graham Appleby (lead), Toshi Otsubo, George Kirchner Mike Pearman, and Dave Arnold to provide a plan for discussion at the fall 2007 AGU on how we should improve the precise computation of the spacecraft CoM offsets for given station-s/c configurations.
### Quicklook Analysis Reports

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<thead>
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<th>Center</th>
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<td>7-Day Arc</td>
<td>SLRF2005</td>
<td>H. Mueller</td>
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A table comparing the parameterization used by the above centers will be available soon.

Analysis reports that are distributed via email, are accessible from the SLReport archives at both the EDC and the CDDIS. Some of the reports above are archived at the Data Centers for redundancy, click on the appropriate links below to gain access to these reports.

- MCC Weekly LAGEOS Analysis Report ([CDDIS, EDC](#))
- Latest CODE combined range bias report
- NICT intensity dependence test (2001-02 and 2003-04)
- 3-Day Arc 2000-2001 LAGEOS-1, -2 rapid-analysis results from [Geoscience Australia](#)
- SLR Quarterly Global Performance Report Cards
- EDC Weekly Global Normal Point Data Volume
- CDDIS Weekly and Monthly Global Normal Point Data Volume

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**Responsible Government Official:** Carey Noll  
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Send us your comments

Last modified date: Friday, December 04, 2009  
Author: Mark Torrance  
Maintained by: Carey Noll
Comparison of the parameterization used by quicklook analysis centers

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<td>Joint Center for Earth Systems Technology (JCET), NASA Goddard, Univ. of Maryland, Baltimore County, Baltimore, MD, USA</td>
<td>Hitotsubashi University 2-1 Naka, Kunitachi, Tokyo 186-8501 Japan</td>
<td>Deutsches Geodatisches Forschungsinstitut, DGFIAltfons-Goppel-Str. 11 80539 München Germany</td>
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<td>Weekly solution for coordinates of global SLR stations and daily Earth Orientation Parameters (x,y-pole, LOD)(SINEX format)</td>
<td>Daily QC report for a number of satellites</td>
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<td>est/d for all sites</td>
<td>not modeled/estimated in orbit determination</td>
<td>not modeled/estimated</td>
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<tr>
<td>troposphere biases</td>
<td>not modeled or estimated</td>
<td>not modeled/estimated</td>
<td>not modeled/estimated</td>
<td>not modeled/estimated</td>
<td>not modeled/estimated</td>
</tr>
</tbody>
</table>

Responsible Government Official: Casey Ney
NASA's Privacy Policy and Important Notices
Send us your comments
Last modified date: Thursday, December 03, 2009
Author: Mark Tarango
# Theoretical Values Computed from Provided Parameters

<table>
<thead>
<tr>
<th>Sat.</th>
<th>Cross section</th>
<th>Range (0 deg.)</th>
<th>Signal strength</th>
<th>Range (45 deg.)</th>
<th>Signal strength</th>
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<td>1.000</td>
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<td>0.039</td>
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<td>Satellite</td>
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<td>Coating</td>
<td>Dihedral Offset</td>
<td>Vendor</td>
</tr>
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<td>-------------</td>
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<td>-----------------</td>
<td>---------</td>
<td>-----------------</td>
<td>--------------</td>
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<td>IPIE</td>
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<td>-</td>
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<td>1.6</td>
<td>uncoat</td>
<td>0.5</td>
<td>ITE</td>
</tr>
</tbody>
</table>

* From David Arnold, private communication
NORMAL POINT CONSTRUCTION FOR OPTIMAL TRACKING
(To be reviewed and validated by the Analysis Working Group)

• Maximum normal point intervals (e.g. 2 minutes for Lageos) have been specified by the ILRS (see http://ilrs.gsfc.nasa.gov/satellite_missions/list_of_satelites/index.html).

ASSUMPTIONS

• The quality of a normal point depends only on the number of single shot contributors;
• The normal point algorithm and choice of interval completely accommodates the accuracy, precision and ranging integrity requirements of accuracy, precision and ranging integrity for that satellite
• Assuming a Gaussian distribution, the normal point will depend on the distribution of the single shot contributors, so the first 100 shots (or any 100 shots taken within the appropriate maximum NP interval) are enough to define a normal point improving on the single shot precision by a factor of ten. Since modern SLR systems have full rate precisions in the neighborhood of 1 cm, normal points would have a precision of about 1 mm.
Any considerations of data distribution are limited to the choreography of normal points within a satellite pass.

This will be application dependent: orbit definition will require different (and less stringent) geometry than that for station positioning.

Orbit definition can be satisfied with observations taken by any station as long as the tracking is continuous: the burden can be shared within the network.

Accurate station location requires strong pass geometry from each station, but the normal points need not be regularly space in time during a pass.

The primary application of the SLR Network tracking LAGEOS I and II is station location.

Earth Orientation has similar requirements for time continuity as orbit definition, so the tracking requirements on ETALON can be relaxed for station location and leave the station location task to LAGEOS. ETALON would play an increased role in the determination of scale if the satellite CoM parameters are as accurate as claimed and if they are applied properly in the analyses.
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The primary applications of the SLR network tracking GNSS are (1) orbit definition and (2) reference frame definition (geocenter, scale and orientation) which has similar pass geometry requirements to orbit definition.

For some orbital requirements GNSS tracking could be shared by neighboring members of a regional network and allow each to multiplex tracking to other satellites with no degradation in GNSS orbit accuracy. This may not be applicable for the reference frame requirements.

Stations should strive for precision as close to one mm as possible for all applications of SLR data.

Normal Point distribution during a satellite pass should be determined by the requirements of the most stringent application for that satellite.
NP Recommendation

- A normal point should be terminated when 100 full rate data points have been accumulated or the maximum normal point interval (i.e. 2 minutes for Lageos) is complete, whichever comes first;

- Sequential normal points on a satellite pass should be separated by at least the maximum normal point interval; if the 100 data points applies and the normal point is terminated in less than the maximum normal interval, the station should move on to another satellite if available, or wait for the remaining time to lapse and resume tracking the same satellite for the next NP;

- Normal points should be spread over the satellite pass with at least 2 normal points for Lageos and 3 normal points for GNSS satellites near acquisition of signal, point of closest approach, and prior to loss of signal; (these numbers must be verified by the AWG).

- On LEO satellites, the stations should capture as much of the pass as possible within ILRS priorities and interleaving procedures.
Quality assessment of the ITRF2008

Still preliminary but close to final

Zuheir Altamimi
Xavier Collilieux
Laurent Métivier
IGN, France
Technique contributions

• IVS: (1980.0 – 2009.0) : Full EOP set (84 sites)
• IGS: (1997.0 – 2009.5) : PM, PMrate, LOD (492 sites)
• ILRS: (1984.0 – 2009.0) : PM, LOD (89 sites)
• IDS: (1993.0 – 2009.0) : PM, LOD (67 sites)

• New local ties since ITRF2005:
  – Tahiti : GPS SLR DORIS
  – Tsukuba: GPS VLBI
  – Herstmonceux: GPS SLR
  – Medicina & Noto : GPS VLBI
  – Greenbelt: VLBI SLR GPS DORIS
  – MAUI/Haleakala
  – San Fernando : GPS SLR

• Parallel analysis by IGN and DGFI
579 sites (920 stations)

461 Sites North
118 Sites South

584 discontinuities
ITRF2008 Datum Specification

- **Origin:** SLR
- **Scale:** Mean of SLR & VLBI
- **Orientation:** Aligned to ITRF2005 (orientation and its rate) using 95 stations located at 79 sites:
  - 55 at northern hemisphere
  - 24 at southern hemisphere
SLR/ILRSA24 Origin and Scale wrt ITRF2008P
Scales wrt ITRF2008P

Scale (mm) with respect to ITRF2008P

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Scales wrt ITRF2008P
Scales wrt ITRF2008P

Scale (mm) with respect to ITRF2008P
Scales wrt ITRF2008P
<table>
<thead>
<tr>
<th>Method</th>
<th>Scale Error (ppb)</th>
<th>Scale Error Rate (ppb/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VLBI</td>
<td>± 0.10</td>
<td>± 0.01</td>
</tr>
<tr>
<td>SLR</td>
<td>± 0.12</td>
<td>± 0.01</td>
</tr>
<tr>
<td>DORIS</td>
<td>± 0.20</td>
<td>± 0.03</td>
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## Transformation Param Fm ITRF2008P To ITRF2005

<table>
<thead>
<tr>
<th></th>
<th>Tx</th>
<th>Ty</th>
<th>Tz</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
<td>ppb</td>
</tr>
<tr>
<td></td>
<td>-0.7</td>
<td>-0.4</td>
<td>-3.8</td>
<td>1.14</td>
</tr>
<tr>
<td></td>
<td>± 0.5</td>
<td>± 0.5</td>
<td>± 0.5</td>
<td>± 0.10</td>
</tr>
</tbody>
</table>

At epoch 2005.0

<table>
<thead>
<tr>
<th></th>
<th>Tx rate</th>
<th>Ty rate</th>
<th>Tz rate</th>
<th>Scale rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mm/yr</td>
<td>mm/yr</td>
<td>mm/yr</td>
<td>ppb/yr</td>
</tr>
<tr>
<td></td>
<td>0.2</td>
<td>0.0</td>
<td>-0.1</td>
<td>-0.01</td>
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<tr>
<td></td>
<td>± 0.1</td>
<td>± 0.1</td>
<td>± 0.1</td>
<td>± 0.01</td>
</tr>
</tbody>
</table>
ITRF2008P PM residuals
ITRF2008P PM residuals

WRMS in µas

<table>
<thead>
<tr>
<th></th>
<th>X-pole</th>
<th>Y-pole</th>
<th>X-pole</th>
<th>Y-pole</th>
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<tbody>
<tr>
<td>GPS</td>
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<td>10</td>
<td>VLBI</td>
<td>142</td>
</tr>
<tr>
<td>DORIS</td>
<td>239</td>
<td>353</td>
<td>SLR</td>
<td>144</td>
</tr>
</tbody>
</table>

AGU Fall 2009 – Session G14A
ITRF2008P PM rate residuals
Concluding remarks

- **ITRF2008**: independent combination from ITRF2005

- **Origin**: almost the same as ITRF2005:
  - 3.8 mm at epoch 2005.0 along Z-axis
  - 0.2 mm/yr along X-axis

- **Scale**: mean of VLBI and SLR
  - **Agreement between VLBI and SLR:**
    - $1.10 \pm 0.13$ ppb (at epoch 2005.0) did we reach the limit of VLBI
    - $0.06 \pm 0.01$ ppb/yr and SLR scale consistency?

  - **Diff (ITRF2005 – ITRF2008P):**
    - $+1.14 \pm 0.10$ ppb (at epoch 2005.0)
    - $-0.01 \pm 0.01$ ppb/yr
GNSS Retroreflector Array Activities

• GNSS Standard established;
• Simulation studies to scope the network requirements for applications (E. Pavlis);
• Daylight ranging study underway (G. Appleby, M. Davis);
• Study in cornercube polarization effects (M. Davis, D. Arnold, and S. Della’Agnello)
ILRS Retroreflector Standards
(Revision September 28, 2007)

- Retroreflector payloads for GPS, GLONASS, and COMPASS satellites should have an “effective cross-section” of 100 million sq. meters (5 times that of GPS-35 and -36) for GNSS satellites;

- **Added Recommendation:** Retroreflector payloads for satellites such as Galileo in higher orbits should scale the “effective cross-section” to compensate for the $R^4$ reduction in signal strength;

- The parameters necessary for the precise definition of the vectors between the effective reflection plane, the radiometric antenna phase center and the center of mass of the spacecraft be specified and maintained with an accuracy of 2 mm.
# Retroreflector Arrays on Lageos and HEO Satellites

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Altitude (MM)</th>
<th>Effective Cross Section (MSqM)</th>
<th>Relative Return Signal Strength</th>
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</thead>
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<td></td>
<td>Zenith</td>
</tr>
<tr>
<td>Lageos1/2 *</td>
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<td>15</td>
<td>1.0</td>
</tr>
<tr>
<td>Etalon1/2 *</td>
<td>19</td>
<td>55</td>
<td>0.032</td>
</tr>
<tr>
<td>GLONASS &lt;115</td>
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<td>80</td>
<td>0.046</td>
</tr>
<tr>
<td>GLONASS 115</td>
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<td>131</td>
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<td>21.5</td>
<td>80</td>
<td>0.028</td>
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<td>GIOVE-A **</td>
<td>23.9</td>
<td>45</td>
<td>0.010</td>
</tr>
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<td>GIOVE-B **</td>
<td>23.9</td>
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<td>0.009</td>
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<tr>
<td>ETS-8 ***</td>
<td>36</td>
<td>140</td>
<td>0.006</td>
</tr>
<tr>
<td>* Sphere</td>
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<tr>
<td>** Galileo Test Satellite</td>
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<tr>
<td>*** Synchronous</td>
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</table>
GLONASS 115

Concepcion

Graz

Yarragadee

Zimmerwald
COMPASS 1M

Normal points for station 7405

Concepcion

Normal points for station 7000

Yarragadee

Normal points for station 7610

Zimmerwald

Normal points for station 7839

Graz
A Possible Plan for Multiple GNSS Tracking

• Assumptions:
  – Satellites carry the enhanced array (factor of 5 increase in effective cross section);
  – Precise Center of Mass information including the change with fuel consumption required for all spacecraft;
  – Many network stations will be using enhanced systems (e.g. KHz ranging, improved detection, ) in the 2013 timeframe for improved performance on weak targets;
  – Increased automation and data interleaving procedures at the field stations will increase ranging efficiency;

• Concepts for an Operational HEO Plan:
  – Support GPS, Galileo, and GLONASS; COMPASS; and possibly other;
  – Pointing predictions based on on-board GPS data and SLR data for improved pointing particularly in daylight using real-time communication;
  – Decrease Normal Point intervals (from 5 minutes) as data volume increases, thereby increasing tracking capacity;
  – Three segments per pass (ascending, middle, descending);
  – Data available for analysis immediately after each pass;
  – Network tracking roster organized for at least 16 GNSS satellites at a time (at least one satellite per orbital plane per system);
  – Tracking cycles set for 30 – 60 days (to cover all satellites within a 12 month period);
  – Greater stress on daylight tracking;
  – Flexible tracking strategies; organized in cooperation with the agencies involved and the requirements for the ITRF;
GGOS

• GGOS Structure
  – Bureau for Networks and Communications established (GSFC);
  – Bureau for Standards and Procedures established (DGFI);
  – Portal being developed (BKG, GSFC);
  – Proposal for a Coordination Center received (ASI)
  – Satellite Mission Working Group established (OSU)

• Publications
  – GGOS 2020 Book
  – Papers at IAG, EGU, AGU, etc

• Meetings
  – GGOS Science Workshop in Finland (June)
  – GGOS Science Session and Steering Committee Meeting at IAG in Buenos Aires (August);
  – Metsovo Workshop on GNSS/SLR synergy (POD, Reference frame, etc.)
  – Workshop on Intergovernmental/Interagency interface for GGOS at BKG in Frankfurt;
  – GGOS Unified Analysis Workshop, San Francisco, December 11 -12;
  – GGOS Bureau for Networks and Communications Meeting, December 16, Chancellor Hotel, San Francisco;
  – GGOS Retreat, Miami FL, February 2 – 4, 2010