ILRS
Governing Board Meeting

April 26, 2005
18:00 - 21:00

Vienna University of Technology
Gusshausstr. 27-29, Room 124, 3rd Floor
Vienna, Austria

ILRS Governing Board Meeting

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Tuesday, April 26, 2005
18:00 – 21:00

Agenda

1.	Opening Remarks (5 min.)	W. Gurtner
2.	ILRS Status/Action Items (15 min.)	M. Pearlman/ C. Noll
3.	NASA SLR Status (5 min.)	D. Carter
4.	Reports from Working Groups (5 min. each)	WG Chairs
	Analysis	R. Noomen/G. Appleby
	Data Formats and Procedures	W. Seemueller
	Missions	H. Kunimori/P. Shelus
	Networks and Engineering	G. Kirchner/U. Schreiber
	Signal Processing	G. Appleby
5.	New Transponder Ad hoc Working Group? (10 min.)	W. Gurtner/U. Schreiber
6.	Russian Space Agency Agreement (10 min.)	M. Pearlman
7.	New ILRS Orbit Product (5 min.)	R. Noomen
8.	Data Analysis and Feed Back/ Station Performance Charts (10 min.)	W. Gurtner/M. Pearlman
9.	Tracking Restrictions (ICESat, ALOS) (10 min.)	W. Gurtner/H. Kunimori
10.	Galileo Geodesy Service Provider: Link to ILRS (5 min.)	W. Gurtner
11.	GGOS Activities (10 min.)	H. Drewes/M. Pearlman
12.	ILRS Fall Workshop (5 min.)	G. Appleby
13.	New Business	W. Gurtner/WG Chairs
14.	Other Business	W. Gurtner

ILRS Governing Board

Ex-Officio Members:

Director, Central Bureau:	Mike Pearlman
Secretary, Central Bureau:	Carey Noll
President of IAG Commission I:	Hermann Drewes

Members Appointed or Elected by Organizations:

EUROLAS Network Representatives:	Giuseppe Bianco
	Werner Gurtner (Chair)
NASA Network Representatives:	David Carter
	Jan McGarry
WPLTN Representatives:	Ben Greene
	Hiroo Kunimori
IERS Representative:	Bob Schutz

Members Elected by their International Peers:

Analysis Representatives:	Graham Appleby
	Ron Noomen
Data Center Representative:	Wolfgang Seemueller
LLR Representative:	Peter Shelus
At-Large Representatives:	Georg Kirchner
	Ulrich Schreiber

Former Members:

Francois Barlier (former At-Large Representative, 1998-2000)
Gerhard Beutler (former CSTG President, 1998-1999)
John Bosworth (former Director, ILRS Central Bureau, 1998-2001)
John Degnan (former Chairman and NASA Network Representative, 1998-2002)
Richard Eanes (former Analysis Center Representative, 1998-2000)
Yang Fumin (former WPLTN Network Representative, 1998-2002)
John Luck (former At-Large Representative, 1998-2002)
Wolfgang Schlueter (former EUROLAS Network Representative, 1998-2002)

ILRS Governing Board Meeting
Action Items

AGU, San Francisco CA
December 13, 2004

1. CB will contact missions such as TOPEX, Envisat, GP-B etc. to remind them that we need recognition in their publications.

    - Messages sent on 4/8 to TOPEX, Envisat, ERS-2, Jason, GFO-1, GP-B, CHAMP, GRACE, GLONASS, and Meteor-3M.

2. CB will contact the IAG Outreach to suggest that the IAG make its participants aware of the issue of service recognition issue in publications, papers, reports, and presentations.

    - IGS, IVS, ILRS, and IDS are working on a joint activity to:

        - Develop a common citation and post it with a notice on their web sites and on their data and product ftp sites;
        - Jointly request that the IAG take positive action (website notice, messages to the community, etc) to activate its community;
        - Consider contacting relevant journals and journal referees to help enforce this citation.

3. CB will contact key TOPEX people to see if we can get an acknowledgement of this new role. (Done)

    - Acknowledgement received from Dr. Lee Fu/JPL on 3/18.

4. CB will draft a term limits provision for WG Chairs for GB review. (Done)

    - Change drafted and approved on 3/22.

5. If we do not hear anything by mid-January, the CB will send a note to Drs. Shargorodsky and Vasiliev.

    - Draft agreement received; to be reviewed at the GB meeting in Vienna
    - Satellites being designed and built now

6. Noll will contact the ACs, AACs, and stations requesting an email address for SLReport. (Done)

    - Noll contacted ACs and AACs
    - Seemueller added requested email addresses to SLReport mailing list

7. CB will check if the local ties have been measured for the Riyadh and Changchun SLR stations.

    - Noll contacted both stations; plans underway to perform survey in future

8. Gurtner will look at the existing list of data problems (previously maintained by V. Husson) on the ILRS website and see if the webpage can be re-activated and updated on a regular basis.

9. CB will contact DGFI (backup combination center) and ask if they are willing to review problems identified by the individual AC solutions and do the follow-up with the stations.

    - Further discussion required at April AWG meeting to clarify task.

ILRS Governing Board Meeting
Action Items
(continued)

10. CB will issue a message to the stations requesting that they try the prediction data sets generated by mission or mission specific providers. (Done)

    - Noll sent email to ILRS stations exploder on 3/18.

11. CB will examine the idea of issuing a call for a volunteer on the dynamic priorities.

12. CB will bring to closure the recommendation on the Galileo request for tracking support. (Done)

    - GB approval sent 2/21 to Galileo mission contacts

13. CB will send a letter broaching the retroreflector issues with the GPS project. (Done)

    - Letter sent to Michael Shaw/DoT on 2/21, but no response yet
    - Some rumors that retro will be included; we need to get an update on the design

14. Appleby will provide web pages on the spacecraft center-of-mass characterizations to Noll for the ILRS website and prepare an SLRMail message to announce the new pages and request inputs for missing areas. (Done)

    - Appleby and Torrence provided additions to ILRS website
    - Noll installed pages and modifications on ILRS website and notified community, requesting review, update, additions
    - Fill in the holes (M. Torrence and G. Appleby)

15. Appleby will send an email to each of the ILRS WG chairs asking for hot topics for the fall 2005 workshop. (Done)

    - Inquiry sent out on 1/28

16. Resolution of OCTL/JPL application for ILRS network station. (Done)

    - Approved by the GB on 3/22

17. SLR Restricted Tracking (Randy Ricklefs)

    - Go – No Go Flag
        - Implemented at Zimmerwald and MLRS
        - In process at Graz and HTSI
        - New field to be added to the file for consistency with the new segment file format
    - Segment file
        - Implemented at Zimmerwald, Graz, and MLRS
        - In process at HTSI
    - Should be ready for discussions on ALOS at EGU

ILRS Governing Board
Recent Actions and ILRS Developments

Network Items:

- EUROLAS
  - Grasse SLR station (7835) to close in early 2005
- WPLTN
  - Yarragadee and SALRO facing issues with funding organizations
  - Shanghai closed 04/2005 for move to new location
  - New Mt. Stromlo station now submitting data routinely
  - GUTS system installed at Tanegashima, Japan
    - System operating in test mode after typhoon damage in 2004
    - Requested review of test data by ILRS ACs
  - GPS receivers at SALRO and in Changchun now part of IGS
    - Local surveys planned but schedule unknown
- NASA
  - JPL's OCTL station accepted as part of ILRS network in March 2005
  - Maui
    - Closed in June 2004
    - Work has begun on refurbishing TLRS-4 for move to Hawaii in late 2005
    - Closeout survey at HOLLAS performed by HTSI in March 2005
  - Arequipa
    - Closed in early 2004
    - Operations to resume in mid-2005
  - GSFC
    - Staff reduction at MOBLAS-7
  - SLR2000
    - Received first returns

Data Issues:

- Data reporting
  - All reports should issue quantity values in passes (not pass segments) and minutes of data (normal points times bin size)
    - Report Card has been updated and is current
    - Some work still to be done at CDDIS here (two weekly reports currently issued; on-line forms)
- CDDIS has modified SLR data archive structure to coincide with operation of new server (start of 2005).

Operations:

- Predictions
  - E-mail sent on March 18, 2005 suggesting stations try sponsor-generated predictions
- Low elevation tracking
  - Data from Grasse, Graz, and Zimmerwald in 2004
  - Data yield still very low
- Developing policy for restricted tracking missions (ICESat, ALOS) (see following pages)
- Dynamic Priorities
  - Planning underway at HTSI

Site Surveys:

- Site surveys conducted at Hartebeesthoek and Shanghai; survey planned for Beijing
- Analysis of survey data from Hartebeesthoek, Shanghai, Hawaii, Arequipa, and GSFC in process
- Closeout survey of Haleakala performed by HTSI in late 2004; analysis underway
- IERS has established a Collocation/Survey Working Group to coordinate ground survey procedures for the IAG Space Geodesy activities (ILRS, IVS, IGS, and IDS)

ILRS Governing Board
Recent Actions and ILRS Developments
(continued)

Mission Items:
- Center of mass web pages implemented on ILRS website (see updated examples following pages)
- Tracking Support Request form for Galileo submitted by ESA
  - Approved by GB February 2005
  - Launch of two test vehicles scheduled for 2005
- Received email from TOPEX project (L. Fu/JPL) stressing need for continued support
  - DORIS receiver failed in November 2004
  - POD produced from SLR only
- Contacted GPS-III regarding retroreflectors on board
- Meteor-3M tracking very weak, but essential for SAGE (average of 7 passes/week in 2004 and 2005)
- Tracking on GP-B going well (average of 22 passes/week in 2004; 29 in 2005)
- Latest Cryosat launch now July 2005

Reports:
- Currently assembling combined 2003/2004 annual report (report on following pages)
  - Emerging technologies section (J. Degnan) still missing
- 14th International Workshop on Laser Ranging in San Fernando, Spain June 7-11, 2004
  - 99 papers (oral and poster) presented; 22 science and applications papers
  - Proceedings website established at ILRS (*http://cddis.gsfc.nasa.gov/lw14*)
  - 69 of 99 papers have been received
  - Proceedings will be issued in both hardcopy and electronic media
- All 2004 and first 2005 ILRS station report cards issued by RITSS
- Submitted ILRS contribution on ILRS co-location and local tie information to IERS for inclusion in the 2003 Matera survey workshop proceedings

Meetings:
- December 13, 2004: Meeting with newly elected ILRS Governing Board at AGU
- December 13, 2004: ILRS AWG meeting at AGU
- April 25, 2005: ILRS MWG and AWG meetings at EGU in Vienna, Austria
- April 26, 2005: ILRS DFPWG and GB meetings at EGU in Vienna, Austria
- August 22026, 2005: GGOS session at IAG Scientific Assembly in Cairns, Australia
- October 3-7, 2005: ILRS Technical Workshop in Eastbourne (near Herstmonceux),
- October 16-20, 2006: 15th International Workshop on Laser Ranging in Canberra, Australia

Other Items:
- INDIGO
  - User assessment performed to identify existing commonalities and opportunities in the IAG services (IGS, ILRS, IVS)
  - Survey of IAG service central bureaus and websites performed
  - Website established *http://indigo.nasa.gov*

ILRS Satellite Tracking Priorities
April 2005

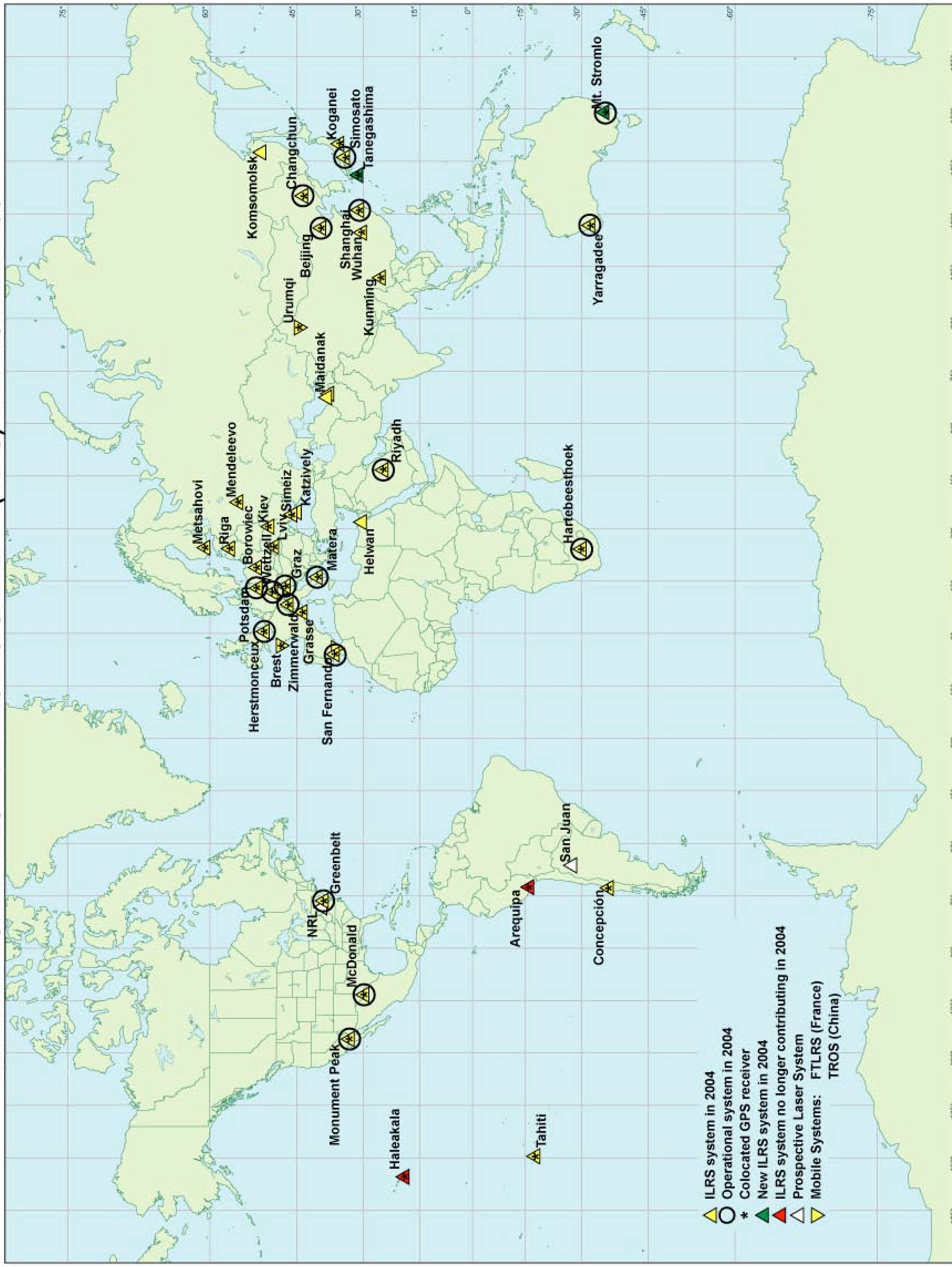
1. Priorities decrease with:
   a. increasing orbital altitude; and
   b. increasing orbital inclination (at a given altitude).
2. Priority of some satellites may then be increased to intensify support for:
   a. active missions (such as altimetry);
   b. special campaigns (such as IGLOS); or
   c. post-launch intensive tracking phases; and
3. Some slight reordering may be done to give higher priority missions with increased importance to the analysis community.

Priority	Mission	Sponsor	Altitude (km)	Inclination (degrees)	Comments
1	GP-B	NASA/Stanford U.	652	90	New mission
2	GRACE-A, -B	GFZ/JPL	485-500	89	Tandem mission
3	CHAMP	GFZ	429-474	87.3	
4	GFO-1	US Navy	790	108.0	Altimetry/no other tracking technique
5	Envisat	ESA	796	98.6	Tandem with ERS-2 tracking to commence 40 days after launch
6	ERS-2	ESA	800	98.6	Tandem with Envisat
7	Jason	NASA/CNES	1,350	66.0	Tandem with Topex
8	TOPEX/Poseidon	NASA/CNES	1,350	66.0	Tandem with Jason
9	Larets	IPIE	691	98.2	
10	Starlette	CNES	815-1,100	49.8	
11	Stella	CNES	815	98.6	
12	Meteor-3M	IPIE	1000	99.6	
13	Ajisai	NASDA	1,485	50	
14	LAGEOS-2	ASI/NASA	5625	52.6	
15	LAGEOS-1	NASA	5850	109.8	
16	Beacon-C	NASA	950-1300	41	Upgraded from campaign to ongoing mission (Jan-02)
17	Etalon-1	Russian Federation	19,100	65.3	Campaign extended to 01-Oct-02
18	Etalon-2	Russian Federation	19,100	65.2	Campaign extended to 01-Oct-02
19	GLONASS-89	Russian Federation	19,100	65	Replaced GLONASS-86 as of 20-Mar-03
20	GLONASS-87	Russian Federation	19,100	65	Replaced GLONASS-88 as of 20-Feb-02
21	GLONASS-84	Russian Federation	19,100	65	Replaced GLONASS-79 as of 22-Feb-01
22	GPS-35	US DoD	20,100	54.2	
23	GPS-36	US DoD	20,100	55.0	

Lunar Tracking Priorities

Priority	Retroreflector Array	Sponsor	Altitude (km)
1	Apollo 15	NASA	356,400
2	Apollo 11	NASA	356,400
3	Apollo 14	NASA	356,400
4	Luna 21	Russian Federation	356,400
5	Luna 17	Russian Federation	356,400

INTERNATIONAL LASER RANGING SERVICE (ILRS) NETWORK IN 2004



Russian Proposal on Novel Satellites (The Lunenberg Lens Revisited)

- We were approached at EGU in Nice in April 2004 by Drs. Shargorodsky and Vasiliev regarding IPIE interest in building and launching "novel" SLR satellites;
- The ILRS sent FSA a letter expressing interest and outlining the importance of these new satellites;
- The FSA is interested and has sent the ILRS a draft agreement that covers their commitment to build such satellites and our commitment to track them and provide access to the data;
- The agreement makes no more of a commitment from us than a normally make with any new mission;
- The agreement has to be cleaned up a bit and signed;
- Design of the satellite(s) is already underway to be ready of a early launch.

SCIENCE-TECHNICAL AGREEMENT

between
the Federal Space Agency of Russia
and
the International Laser Ranging Service

The Federal Space Agency of Russia (referred below as ROSKOSMOS), and the International Laser Ranging Service (referred below as ILRS) being a part of the of the International Association for Geodesy (IAG), referred together as Parties, following the will to develop cooperation in space research and of its use for peaceful purposes, within the area of high-precision satellite laser ranging, and

taking into account the importance of further increase of the measurement precision and limitations in the existing approaches, and therefore the need for a new conception to achieve this goal;

taking into account the appreciation by the international satellite laser ranging community of the minimum-target-error satellite conception proposed by IPIE, which may provide a breakthrough towards new frontiers of precision;

taking into account the extreme importance of millimeter- and submillimeter- accuracy satellite laser ranging for solving of fundamental and applied problems, including prediction of earthquakes;

agreed to cooperate in development of terrestrial and space-based means of satellite laser ranging, in the following directions.

Clause 1

ROSKOSMOS, within the Federal Space Program:

- will provide development, manufacturing and launching as a piggyback load of an IPIE-proposed spherical glass satellite based on the Luneberg lens concept;
- will provide, through the leading information collection and processing center MCC-M, quick delivery of ephemeris for tracking of the spherical glass satellite;
- will equip at least one of the Russian laser tracking stations in operation with upgraded measurement equipment;
- will take efforts to establish contacts between ILRS and other Russian SLR stations within this work.

Clause 2

ILRS, on request from the Russian Party, will provide tracking by its global SLR network, collection and exchange of data, and cooperation in their analysis and investigation; ILRS will also cooperate in evaluation of the satellite parameters during its spaceflight. The ILRS analysis centers will, together with the Russian analysis centers, work on data evaluation and on use of the data for scientific purposes.

Clause 3

Contact persons from Federal Space Agency of Russia are:

- V.V. Simonov, Head of Department, FSA
- Prof. V.D. Shargorodsky and Prof. V.P. Vasiliev, IPIE

Contact persons from ILRS are:

- Dr. Michael Perlman, Director of the ILRS Central Bureau
- Dr. Werner Gurtner, Chairman of the ILRS Governing Board

Clause 4

The Agreement is made in Russia and English. Both texts have equal force.

The Agreement takes force from the moment of its signing, and will remain in force till December 31, 2010, with automatic prolongation for subsequent 5-year-long periods, if any of the Parties does not notify the other Party on its intention to stop its action 6 months before the end of the corresponding period.

From ILRS

From FSA

From IPIE

Data Analysis and Feed Back/Station Performance Charts

Werner Gurtner
April 15, 2005

After the budget cuts for SLR by NASA, the reduction of staff at the ILRS Central Bureau led to a significant loss of performance with regards to data quality assessment, feed back and documentation:

- Maintenance of a catalogue of data problems:
  The file **slr_data_corrections.snx** to be found at ftp://cddis.gsfc.nasa.gov/pub/slr/data/ was last modified on July 14, 2003. The format selected for this problem catalogue is SINEX. The data (list of problems, table of biases) is stored in a special BIAS/EPOCHS block and in the known SOLUTION/APRIORI block. It seems to me rather complicated, both for generation as well as for inspection and interpretation.
- The routine screening of the various weekly analysis reports, detection and keeping track of unusual station behavior by Van Husson was discontinued
- The quarterly station performance plots were discontinued, although, as a certain compensation, a new table ("Table 2") was created:

Table 2

Site Information		Delft Orbital Analysis				NICT Orbital Analysis				MCC Orbital Analysis				SHAO Orbital Analysis			
Station Location	Station Number	NP RMS	short term (mm)	long term (mm)	% good LAG. NP	NP RMS	short term (mm)	long term (mm)	% good LAG. NP	NP RMS	short term (mm)	long term (mm)	% good LAG. NP	NP RMS	short term (mm)	long term (mm)	% good LAG. NP
Baseline		10.0	20.0	20.0	95	10.0	20.0	20.0	95	10.0	20.0	20.0	95	10.0	20.0	20.0	95
Yarragadee	7090	8.7	10.2	5.3	100.0	1.9	22.6	13.1	100.0	2.0	16.0	4.1	97.7	2.0	15.6	5.0	95.5
Riyadh	7832	11.2	14.0	3.2	99.9	3.1	25.9	9.1	100.0	3.3	37.4	23.0	96.9	3.4	28.1	17.9	96.1
Zimmerwald	7810	9.3	12.3	4.2	100.0	2.3	14.7	9.9	100.0	2.7	8.0	3.2	93.8	2.2	14.1	8.0	94.6
Graz	7839	8.4	9.4	2.0	100.0	1.1	13.0	5.6	100.0	2.1	7.9	3.6	100.0	1.7	15.1	2.1	96.0

Unrelated to the budget cuts at NASA there are additional weak points in the quality assessment:

- UTX/CSR stopped generating weekly pass reports. As they were used as a certain bench mark for quality assessment it is not clear how to replace them.
- The various weekly analysis reports (range and time biases, precision, # of rejected normal points) (currently 5: DGFI, DUT, MCC, NICT, SAO) are difficult to compare: They differ in format, generation date, covered time period, contents, used meta data like station coordinates, rejection criteria, etc. At least some of the reports are generated independently from the weekly analysis for the IERS combination project.
  In order to make it easier to cross-compare the various weekly analysis reports the *ILRS Combined Range Bias Report* is generated and distributed by SLReport every week.
- It is unclear to what extent data problems found at the end of the analysis chain flow back to the stations or are verified across the various analysis centers, especially for non-geodetic satellites like Jason, Envisat, CHAMP, etc.
- Most of the weekly analysis reports cover LAGEOS-1 and LAGEOS -2 only

EDC started to implement the same basic data checks for the incoming data as HTSI has been using for many years. These checks mainly aim at those problems (like format inconsistencies or gross errors in meta data) that can be detected without actual data analysis.

In addition to the weekly analysis discussed above Herstmonceux is checking the ranging data at different levels:

- within the near real-time time bias computation (latency < 1 hour)
- long arc solutions
- short arc solutions for station clusters

These tests cover most of the satellites tracked by ILRS

The CODE analysis center provides daily checks of GPS and GLONASS normal point data (comparison with precise microwave orbits).

Conclusions

Data quality assessment in ILRS can be done at various levels; each level has its own capabilities and advantages:

- On site
- At data centers
- Individual and special quality checks by various analysis centers
- Quality assessment during final processing at ILRS analysis centers or mission centers
- Cross-comparison of individual analysis center solutions during the combination procedures for the IERS combination project

There is no provision taken to actually collect, compare and interpret the various quality assessments and to generate a consistent and concise catalogue of station/data problems to be archived for the future.

There is no provision taken to make sure that all analysis centers are aware of and deal with the same data problems. A bias detected at one analysis center can go undetected by another one.

There is no provision taken that **all** identified data problems actually flow back to the stations for proper action.

Proposal:

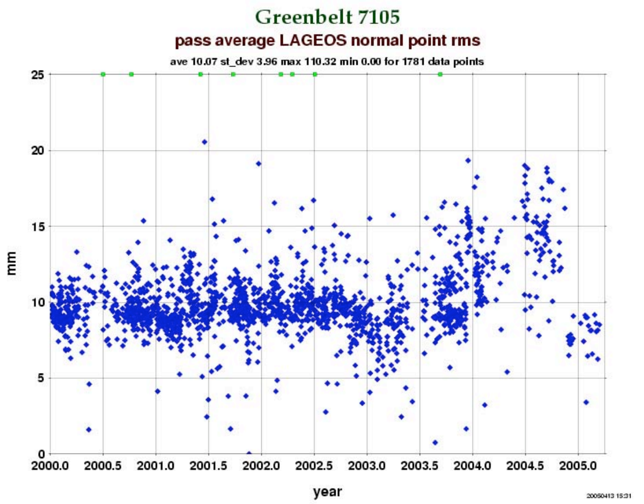
ILRS looks for an institution that acts as a clearinghouse for identified data problems and that generates and maintains a catalogue of confirmed such problems. The ILRS combination centers certainly have a privileged position for such a task because they analyze normal point data and they analyze and combine solutions of all contributing analysis centers.

April 15, 2005

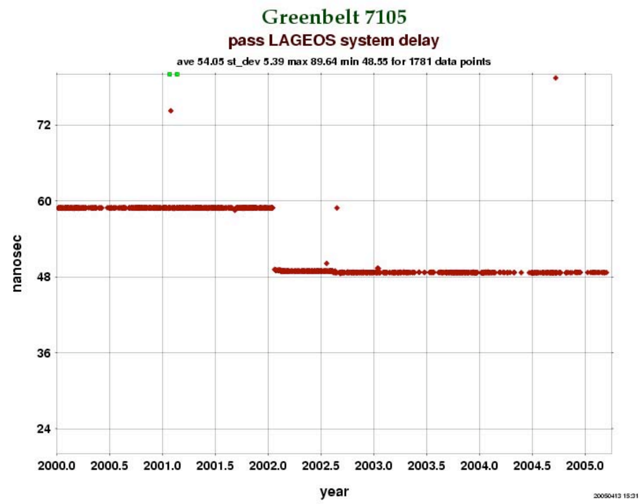
W. Gurtner

Station Performance Charts

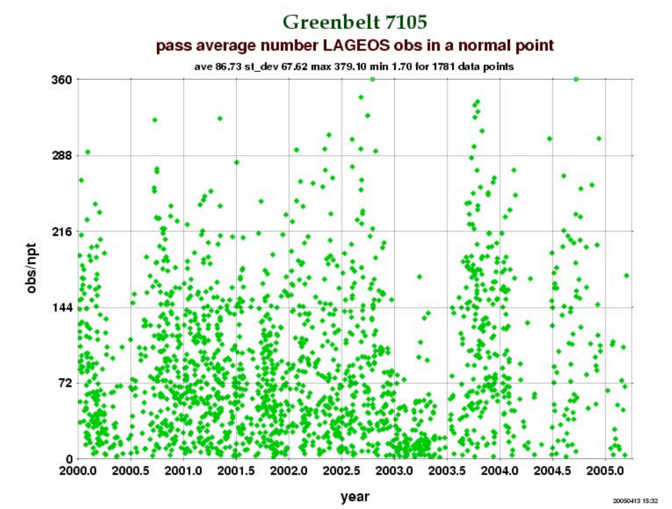
Mark Torrence/RITSS



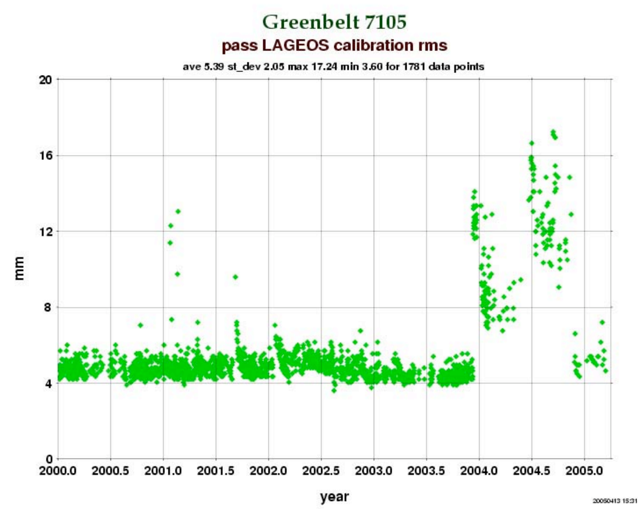
Pass Average LAGEOS Normal Point RMS for Greenbelt



Pass LAGEOS System Delay for Greenbelt



Pass Average Number of LAGEOS Observations/Normal Point for Greenbelt

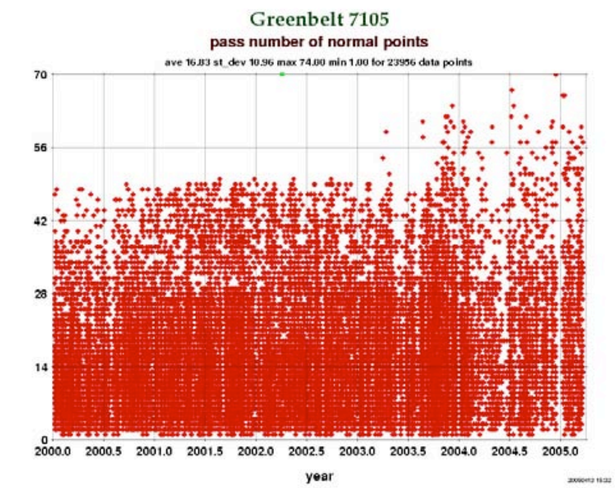


Pass LAGEOS Calibration RMS for Greenbelt

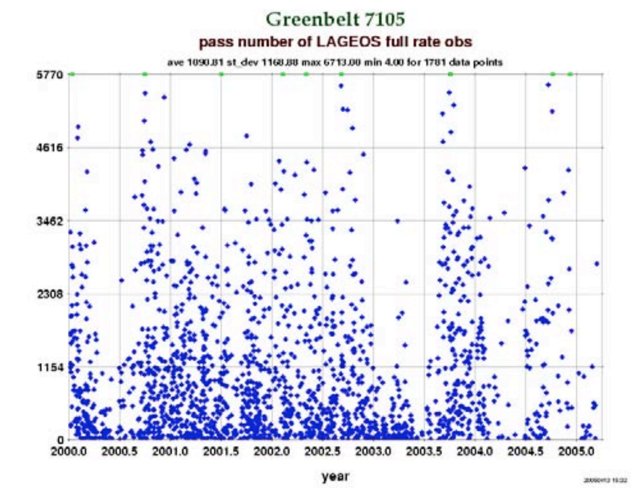
International Laser Ranging Service

Station Performance Charts

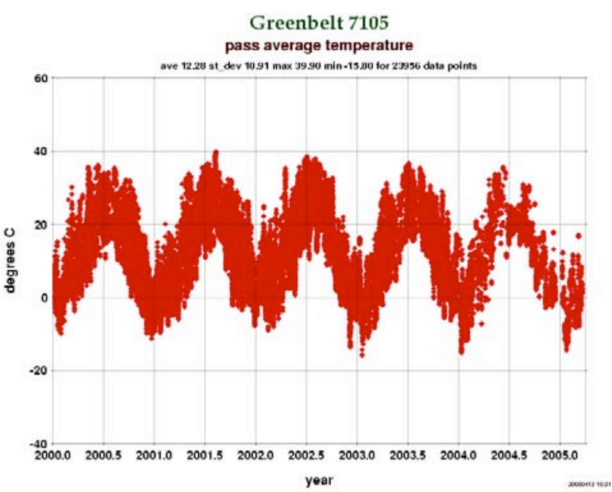
(continued)



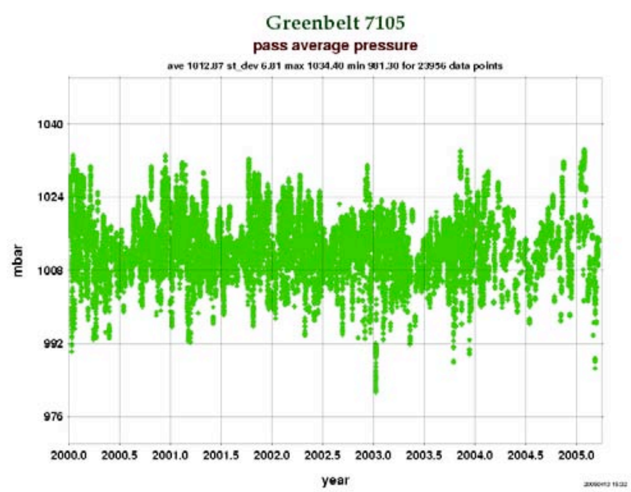
Number of Normal Points per Pass for Greenbelt



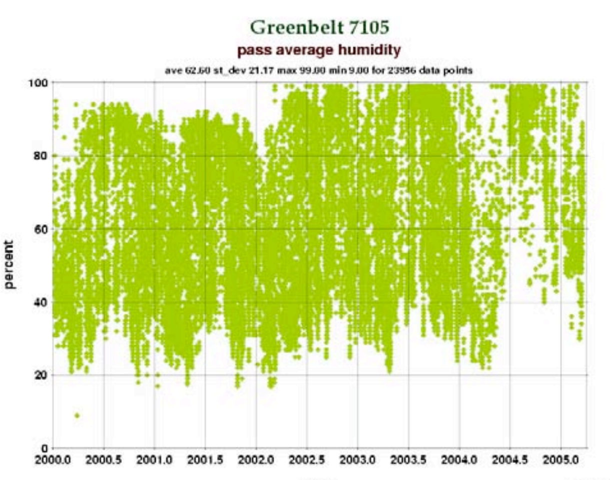
Number of LAGEOS Full-Rate Observations for Greenbelt



Average Pass Temperature for Greenbelt



Average Pass Pressure for Greenbelt



Average Pass Humidity for Greenbelt

Restricted Laser Tracking of Satellites

Werner Gurtner
August 13, 2004

Modifcations: September 27, 2004 (verification with full-rate data)
September 28, 2004 (prediction sets)
January 20, 2005: Go - nogo key
April 12, 2005: Proposal for format change

1. Introduction

There are satellites that must only be tracked by laser ranging under certain restrictions or conditions:

- The corner cubes may not be visible under certain geometric conditions.
- An example is the Gravity Probe B. Its corner cubes are mounted on the back plane of the satellite. As the satellite is actively kept at a constant orientation in space the corner cubes are only visible from a specific station during part of the possible passes.

  Tracking outside the effective pass interval does not harm the satellite but no returns are possible.
- Some satellites are equipped with optical sensors that may be damaged by the SLR laser beam if the station is within the field of view of this optical sensor. Depending on the way the sensors are used (fixed nadir orientation, swept left and right to the satellite orbit, programmed off-nadir pointing) the pass restrictions can be more or less complicated. We need to be within the operating range of the corner cubes, yet out of the vulnerable range of the detectors.
  - Fixed nadir pointing: The "forbidden" zone for laser tracking is symmetric around the station's zenith with a maximum elevation depending on the field of view of the sensor and an appropriate safety allowance;
  - Off nadir pointing: Some options here include
    1. sweeping motions perpendicular to the satellite orbit which can lead to one short forbidden time interval when the station is within the sweeping band of the sensor;
    2. fixed or programmed off-nadir pointing which may lead to forbidden time intervals in any part of a satellite pass
  - In case of multiple sensors there may be more than one forbidden time interval per pass

With fixed nadir pointing, the satellite can be protected by imposing a maximum allowable elevation for the station to operate. The elevation would be pass dependent and all ranging to the satellite must cease above this level.

For off-nadir pointing, operating restrictions at each station will depend upon station position, spacecraft position and orientation, and the field of view of any vulnerable on-board detectors. In general this information will not be available at the stations, and the respective satellite mission control center must provide the tracking constraints to each of the participating stations in advance.

In cases where satellites can be repositioned or re-oriented to a non-nominal direction (actively or because of an attitude control system failure) it may be necessary to update these tracking or viewing constraints in a very short timeframe. In some cases it may not be practical or prudent to issue long-term viewing constraints which may inadvertently place the satellite in jeopardy.

In order to be able to track the satellites under such restrictions, we need to:

- Set up procedures to prevent a station from inadvertently damaging the vulnerable satellite equipment;
- Define an acceptance procedure for stations to pass before any laser tracking on the relevant satellite can begin;
- Relieve the accepted stations from any legal reliability or financial consequences in case of unintentional damage

2. Procedures

2.1 Fixed nadir pointing

The mission control center for the relevant satellite defines the maximum elevation (including a safety factor) up to which laser ranging can be performed. For the time interval during which the satellite is above this maximum elevation, the tracking system has to shut down / block the laser automatically. An additional level of safety can be added by splitting the pass into two independent segments, so that the system will not track the pass segment above the maximum elevation, at all.

The defined maximum elevation can include a maximum off-nadir pointing angle within which the satellite can operate. If this angle is small it may be more effective to decrease the maximum elevation accordingly to avoid having to compute individual pointing-dependent pass segments.

Example: Icesat: Maximum elevation set to 70 degrees

2.2 Off nadir pointing (pass- and station-dependent forbidden zones)

In cases where corner cubes or vulnerable detectors are pointing to off-nadir positions satellite passes may have to be divided into more complicated pass segments. The mission control center will generate a station-dependent pass segment list or viewing table and distribute it to the stations in advance.

As stations may use different minimum elevations for different satellites or weather conditions or depending on their actual horizon mask, the pass segment lists will be based on a low minimum elevation angle, e.g. 5 degrees. Stations will set their own minimum elevation angle as required.

The pass segment list (see below) will contain all pass segments for a time period to be selected by the mission control. The list will include the station code, the satellite name, the start and end dates/times for all pass segments, the maximum elevation for each pass segment, and the segment length. The following example defines the contents and format of the list.

Example:

```
Satellite          :  GP-B
Generation Date    :  2004-07-23 19:07:00 [UTC]
Generated by       :  GP-B Mission Operations / Stanford University
Minimum Elevation  :  5 deg
--------------------------------------------------------------------
                  Start Date/Time      End Date/Time    MaxEl  Durtn
 ID     SAT            [UTC]               [UTC]         [deg]  [min]
---- ---------- ------------------- ------------------- ---    -----
1824 GP-B       2004-07-24 00:46:57 2004-07-24 00:53:51  80      6.9
1824 GP-B       2004-07-24 02:23:59 2004-07-24 02:28:26  10      4.4
1824 GP-B       2004-07-24 11:51:43 2004-07-24 11:55:45  27      4.0
1824 GP-B       2004-07-24 13:29:21 2004-07-24 13:33:19  27      4.0
--------------------------------------------------------------------
                  Start Date/Time      End Date/Time    MaxEl  Durtn
 ID     SAT            [UTC]               [UTC]         [deg]  [min]
---- ---------- ------------------- ------------------- ---    -----
7810 GP-B       2004-07-24 00:47:15 2004-07-24 00:52:53  13      5.6
7810 GP-B       2004-07-24 02:25:23 2004-07-24 02:32:23  67      7.0
7810 GP-B       2004-07-24 04:02:14 2004-07-24 04:05:52   7      3.6
7810 GP-B       2004-07-24 13:28:30 2004-07-24 13:32:27  27      3.9
```

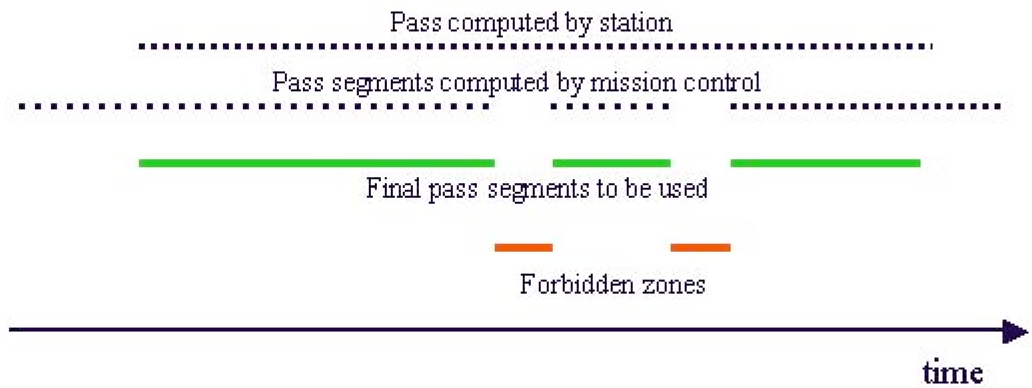
Proposal for format change: (in discussion in April 2005: Include COSPAR, SIC)

```
------------------------------------------------------------------------------
                                 Start Date/Time      End Date/Time   MaxEl Dur
ID      SAT      COSPAR  SIC          [UTC]               [UTC]       [deg][min]
---- ---------- ------- ---- ------------------- ------------------- -- -----
1824 GP-B       0401401 8603 2005-03-12 08:02:24 2005-03-12 08:08:00 15   5.6
1824 GP-B       0401401 8603 2005-03-12 09:40:29 2005-03-12 09:47:21 71   6.9
```

A file may contain pass segments for more than one station, see the example. A station can easily extract its records from the pass segment list (e.g., using the UNIX grep utility).

The station will "fold" these pass segments onto the locally computed pass start and end times to generate the valid pass definition.

Example:



By following the prescribed schedule, the tracking system will range to the satellite only within the accepted pass segments, switching off the laser beam during the forbidden time intervals.

In case of mere geometrical blockage, like e.g., for GP-B, the existence of a pass segment list is not mandatory for tracking.

2.3 Additional safety measures

Additional safety measures can be in force:

- Stations can only be allowed to track passes that are included in the pass segment list. If the pass is not on the list or if the station does not receive the list, then the station ***must not*** track.

- Stations are only allowed to use the prediction sets provided by or designated by the responsible mission control. ILRS will not allow other centers to generate and distribute predictions for such satellites.

- Some of the vulnerable satellites will be maneuvered or reoriented with little notice. Others may have immediate maintenance or attitude control lapses: To prevent stations from tracking during abnormal conditions a special "go - nogo key" file may be maintained by mission control. Stations have to access this key (e.g, ftp) less than 15 minutes before tracking and, till the end of the pass, in intervals defined in the file. Tracking is not allowed if the key is set to "nogo" or if the key cannot be accessed.

  The file (one line) contains the 7-digit Cospar number , the 4-digit SIC of the satellite, the requested control interval (minutes, zero if not used) and the go / nogo key.

  Filename: 'satellitename'.gng (satellite name without blanks, hyphens or underscores)
  Format: I7.7,1X,I4.4,1X,I2,1X,A4

Examples:

```
0300201        8201        10        nogo
0509901        9999                0        go
```

Proposal for format change: (in discussion in April 2005: Include satellite name)
Format: A10,1X,I7.7,1X,I4.4,1X,I2,1X,A4
ICESAT 0300201 8201 5 go

3. Acceptance procedures

3.1 Description of the tracking system procedures

Each SLR tracking station must prepare a detailed description of its procedure to handle the restricted tracking of vulnerable satellites, e.g.:

- Incoming mail processing: Interval, software used
- Computation of start- and end-times of passes
- Procedure to compute actual pass segment start and end times, i.e. including restrictions
- Handling of pass segments: As individual passes or as one pass with laser beam blockages during forbidden zones
- Start of tracking
- Degree of automation, manual interaction
- Laser control / interruption
- Verification of non-operation in case of missing pass segment definitions or predictions of the current day
- Assessment of possible failures of procedures

3.2 Test campaign

For each candidate station, the mission control center will prepare a test campaign with a suitable satellite by sending an appropriate pass segment list under the same restrictions/conditions as the satellite in question.

The candidate station will track the test satellite under the restricted rules for at least ***five successful passes***. The station will send a report of the tracked passes to the mission control center, together with a list of the effective pass segment start and end times.

Stations capable of pass interleaving should track about half of the test passes without and half with pass interleaving.

The mission control center will also verify that the forbidden zones were properly omitted from tracking using the submitted ***normal point data***. The mission control center can also ask for ***full-rate data*** of the test passes to do the verification on a more detailed level.

3.3 "Dry run" on the vulnerable satellite

After successful restricted tracking of the test satellite the station will be asked to successfully track ***three passes*** of the vulnerable satellite ***without laser ranging*** and submit a report about this "dry run" tracking to the mission control center.

Finally the mission control center will send the candidate station a written authorization to include the satellite into its routine tracking with a written waiver of any legal liability.

Copies of all reports and authorizations have to be sent to the ILRS Central Bureau.

3.4 Verification of actual passes

The mission control center can request ***full-rate data*** of the first few actual passes and occasionally later during the mission life time to do a more detailed verification of the proper handling of the restricted pass segments. KHz-Stations will decimate the full-rate test data to 10 Hz before submission.

4. Liability in case of unintentional damage

The mission control center and the ILRS will prepare a written document relieving the accepted tracking station of any liability or financial consequence in case a component of the satellite is unintentionally damaged by the laser beam.

Draft
Agreement between ILRS Stations and Satellite Missions Regarding Issues of Liability for Spacecraft Damage due to Laser Ranging Operations

The is an agreement between the ABC Station (hereafter identified as "the Station") and the DEF Mission Sponsor (hereafter identified as "the Sponsor" for the tracking support of the XYZ Satellite (hereafter identified as "the Satellite").

The Station as an entity within the International Laser Ranging Services (ILRS) agrees to make its best effort to track the Satellite according to the ILRS agreement with the Sponsor. Data will be provided on a daily basis through the ILRS Data Centers. The Sponsor agrees to provide all predictions and scheduling information.

In consideration of the Satellite Laser Ranging (SLR) data provided by the Station on the Satellite, the Sponsor agrees not to make any claims against the Station or station contractors or subcontractors, or their respective employees for any satellite damage arising from these ranging activities, whether such damage is caused by negligence or otherwise, except in the case of willful misconduct.

Tracking of the Satellite by the station will commence only after the Sponsor has agreed that satellite safety programs being implemented at the Station are sufficient to protect the satellite.

Any insurance deemed necessary by the Sponsor, will be obtained by Sponsor at no cost to any of the ILRS entities including the stations.

The Sponsor and the Station shall consult promptly with each other on all issues involving interpretation or implementation of this agreement. Any matter that is not settled before implementation shall be referred to the appropriate Satellite program manager. The program manager will attempt to resolve all issues arising from the implementation of this agreement. If he or she is unable to resolve such issues, then the dispute will be referred to the agreement signatories, or their designated representative for joint resolution.

This agreement will go into effect upon the date of the final signature for a period commensurate with the agreed ILRS term of support for the Satellite. It may be amended by mutual agreement or terminated by one party providing written notice to the other party at least six months prior to the intended termination date or as funding constraints may dictate.

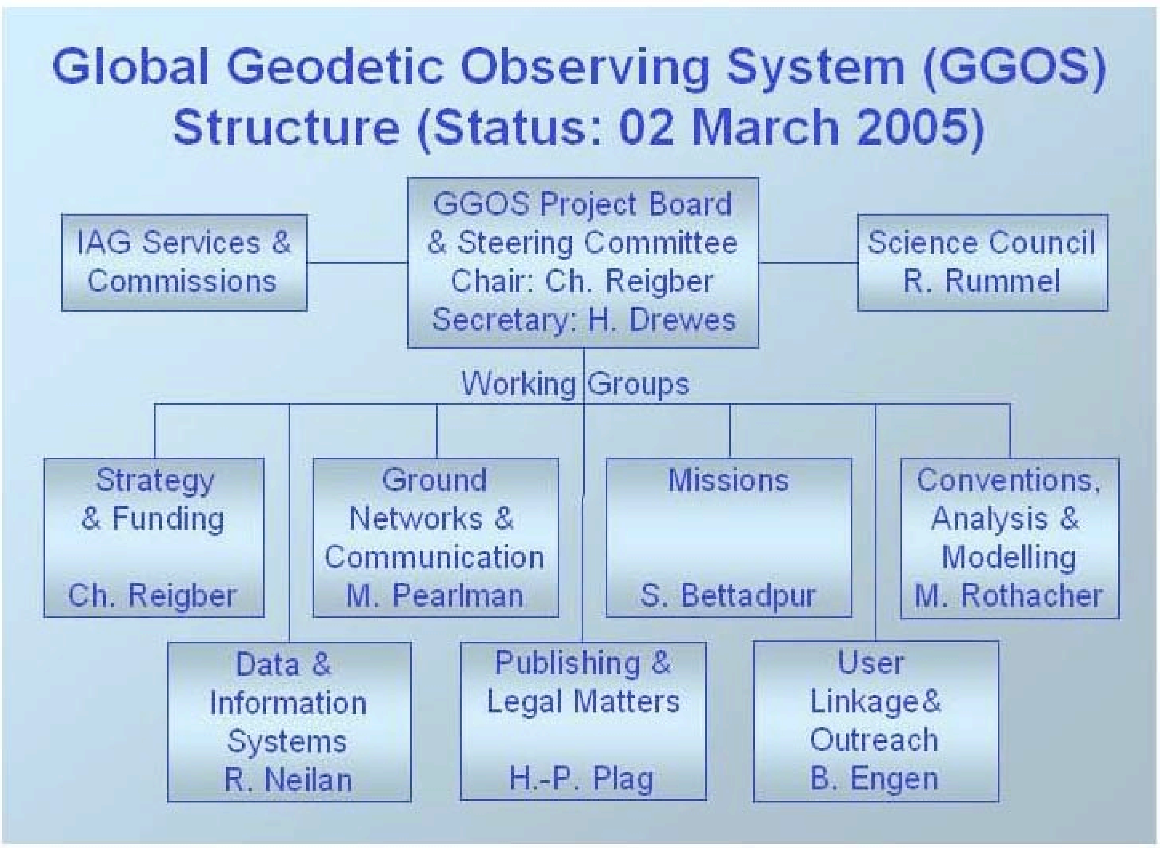
Date	Date
<u>Representative of the Mission Sponsor</u>	<u>Representative of the Station</u>
Name, Title	Name, Title
<u>Signature</u>	<u>Signature</u>

Global Geodetic Observing System (GGOS)

Mike Pearlman/CfA

Mission

- Ensure the collection, archiving and accessibility of all geodetic observations and models as well as the robustness of the estimated parameters in the three fields of geodesy (1) geometry and kinematics, (2) orientation and rotation, and (3) gravity field of the Earth.
- Emphasize the consistency between the different geodetic standards, models and products, and the maintenance of stable geometric and gravimetric reference frames.
- SLR is a key element for these objectives because it contributes to all three fields. Due to the very long observation and derived parameter series it guarantees the long-term stability more than any other geodetic technique.



GGOS Highlights

- Activities underway to get GGOS integrated with several international science and political activities
- Meeting in Potsdam on March 1 & 2
- Slight reorganization of Working Groups
- GGOS website at *http://www.ggos.org*
- GGOS Session at IAG in Cairns in August 22 – 26
- GGOS definition phase to be completed by Cairns
- GGOS review by IAG at Cairns

Global Geodetic Observing System (GGOS)

Mike Pearlman/CfA

(continued)

Networks, Communications, and Infrastructure Working Group

- Task: “working with the IAG Measurement Services to develop a strategy for building, integrating, and maintaining the fundamental network of instrument and supporting infrastructure in a sustainable way to satisfy the long-term (10 – 20 years) requirements identified by the GGOS Science Council.”
- Early stops in this process:
  - quantify the “quality” of what the current networks are producing
  - settle on a strategy to design the geodetic network using our understanding of where we are, where the techniques are going, and what future scientific requirements we will be asked to support.

Members of the Working Group:

- IVS: Chopo Ma, Zinovy Malkin
- IGS: Angie Moore, Norman Beck
- ILRS: Mike Pearlman, Werner Gurtner
- IDS: Pascal Willis
- IGFS: Rene Forsberg, Steve Kenyon
- Data Centers: Carey Noll
- ITRF and Local Survey: Zuheir Altamimi, Jinling Li
- Analysis: Erricos Pavlis, Marcus Rothacher
- Oceanography: Steve Nerem

How do we optimize the networks? (Initial thoughts from a small meeting on March 29

- In the absence of any definitive guidance yet from the GGOS Science Council we will look toward mm accuracies for relatively short time periods.
- No matter how well blessed we are in future budgets, we will be strapped for funds and must rely heavily on international cooperation and existing instruments, facilities, and infrastructure;
- Long time series of data is critical to the stability of the reference frames; stations that are well established and producing high quantity and high quality data should be maintained;
- Degradation of the reference frames may be slow as networks degrade; the “memory factor” may be strong;
- The best results will be achieved with collocation of techniques; ground surveys of collocated instruments must be well maintained;
- Using the most recent International Terrestrial and Celestial Reference Frames (ITRF, ICRF), examine the degradation of the reference frames and their products without each of the measurement techniques (one at a time); what contribution does each
- Instead of optimizing as a single network of all of the techniques; it may be more realistic to optimize each of the networks based on its strongest or unique contributions to the reference frames and the other required geodetic products.
- We need to decide what these critical contributions are from each network;
  - VLBI : Nutation, UT1, Polar Motion
  - SLR : Earth Center of Mass, Scale, POD on passive satellites, etc
  - GPS : Station position and motion; POD for LEO satellites, Navigation
  - DORIS – POD for DORIS satellites, ??
- Some and probably all of the networks are below their optimum number of stations, performance and optimum geographic distributions. Using real data, examine how the key products for each technique degrade as (1) the number of stations is decreased, particularly in regions that are already sparsely covered and (2) data yield per station is decreased (cut in half?). Are we near the “knee of the curve”?
- Develop simulations for each technique to study how the key products would improve as we add stations, move stations around, and improve capability. See if we can find the “knee of curve”. We will need to model the errors and the data yield.

Global Geodetic Observing System (GGOS)

Mike Pearlman/CfA
(continued)

Anticipated Technique Improvements

- SLR
  - Better global distribution;
  - Kilohertz ranging
  - Autonomous operations
  - Improvements in control systems for better interleaving of satellites
  - Interstation scheduling to enhance satellite coverage
  - More compact retroreflector arrays to improve accuracy
  - Continuous data flow and more rapid availability of products
  - Transponder operations for terrestrial and extraterrestrial applications
  - Communications applications
- GPS
  - New satellites with GNSS signal
  - GLONAS and Galileo
  - Improved processing (to provide near real time orbits?)
  - VLBI
  - Improve automation to overcome observation gaps
  - Improvements in the recorders
- VLBI
  - Smaller antenna and fully digitized back-ends
- DORIS
  - G3 Beacons
  - Launch of additional satellites with DORIS tracking (eg Cryosat);
  - Dual channel tracking capability allowing a densification of the network

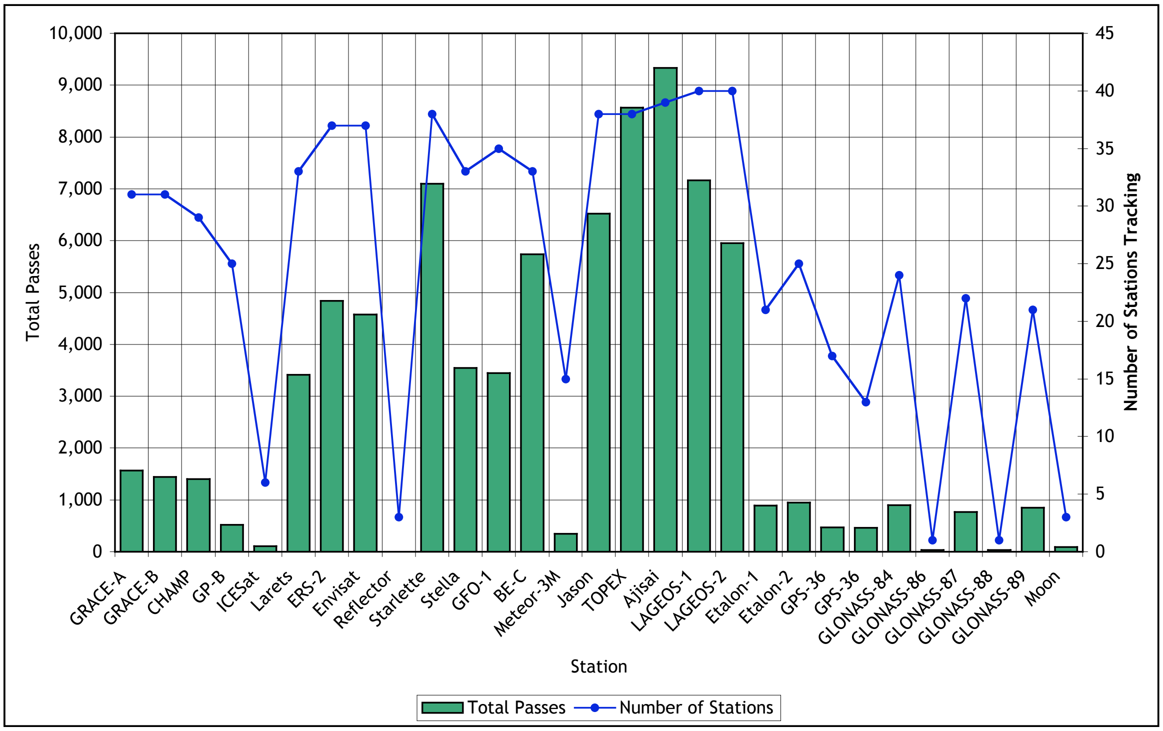
ILRS Quarterly Report Card (Table 1, 04/01/2004-03/31/2005)

Site Information		Data Volume									Data Quality		
Column 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Location	Station Number	LEO pass Tot	LAGEOS pass Tot	High pass Tot	Total passes	LEO NP Total	LAGEOS NP Total	High NP Total	Total NP	Minutes of Tracking	Cal. RMS	Star. RMS	LAG RMS
Baseline		1000	400	100	1500								
Yarragadee	7090	8547	1376	1046	10969	154580	17034	9019	180633	125206	5.0	8.7	9.2
Riyadh	7832	4628	1147	749	6524	65576	10124	4191	79891	62135	9.7	11.9	17.4
Zimmerwald	7810	4760	990	637	6387	118157	22615	6827	147599	115787	16.9	19.6	21.2
Graz	7839	5031	803	457	6291	101905	9780	3783	115468	66909	2.1	4.0	8.0
Wettzell	8834	4860	957	447	6264	63098	6961	2504	72563	46670	3.1	10.4	15.8
Monument_P	7110	4129	675	246	5050	62219	5187	1828	69234	37998	5.7	12.7	13.6
Herstmonce	7840	3457	722	217	4396	53431	8490	982	62903	37145	7.9	12.6	15.8
Changchun	7237	3130	447	140	3717	39643	4288	723	44654	24523	11.2	14.9	15.0
Mount_Stro	7825	2050	720	302	3072	30941	10587	1856	43384	41149	3.2	6.5	7.8
San_Fernan	7824	2290	257		2547	33749	1321		35070	12955	7.9	11.2	18.4
Simosato	7838	1773	516	7	2296	37604	8773	72	46449	29673	11.4	15.7	16.9
Matera	7941	1570	514	195	2279	23260	4851	1330	29441	23946	2.0	4.1	5.9
Greenbelt	7105	1853	226	81	2160	39571	2369	653	42593	19406	5.8	8.5	8.7
Hartebeest	7501	1681	367	108	2156	23821	3780	893	28494	20219	5.2	8.2	9.4
Beijing	7249	1617	292	143	2052	24458	3060	1004	28522	18474	12.2	161.6	24.3
McDonald	7080	1340	381	189	1910	17773	3631	954	22358	17157	10.6	12.2	12.7
Shanghai	7837	1628	258	16	1902	24437	2613	118	27168	13303	10.6	19.3	22.8
Potsdam	7841	1485	286	14	1785	29531	3609	99	33239	15733	10.4	6.6	9.1
Riga	1884	1275	105		1380	23948	1134		25082	8284	7.5	15.9	15.2
Grasse	7835	838	136		974	18571	1509		20080	7987	5.7	10.1	17.1
Borowiec	7811	788	170		958	13700	1872		15572	7609	16.0	18.0	21.0
Kiev	1824	880	69		949	9118	402		9520	3403	58.7	75.5	70.7
Maidanak	1864	499	237	137	873	6372	1577	592	8541	8164		51.5	58.5
Papeete	7124	617	61		678	8037	370		8407	3273	5.7	7.5	7.2
Simeiz	1873	487	136	32	655	4562	801	152	5515	3835			80.4
Urumqi	7355	428	118	4	550	6034	1326	17	7377	4481			
Katzively	1893	439	101	6	546	7268	736	26	8030	3825	57.3	57.1	
Metsahovi	7806	358	29	1	388	5588	220	6	5814	1947	9.9	16.3	19.0
Lviv	1831	294	66		360	4801	587		5388	2753	12.8	31.1	53.9
Concepcion	7405	260	86	7	353	2775	607	23	3405	2327	8.8	42.0	62.3
Haleakala	7210	276	51	7	334	4475	559	35	5069	2604			
Helwan	7831	257			257	2613			2613	841	6.0	17.4	
Wuhan	7231	137	36		173	1785	250		2035	1104	12.5		
Koganei	7308	107	40	16	163	1498	381	111	1990	1959	10.4	14.9	15.7
Potsdam	7836	62	11		73	894	105		999	428			
Komsomolsk	1868	3	9		12	9	66		75	136			
Tanegashim	7358	1	2		3	17	16		33	40			

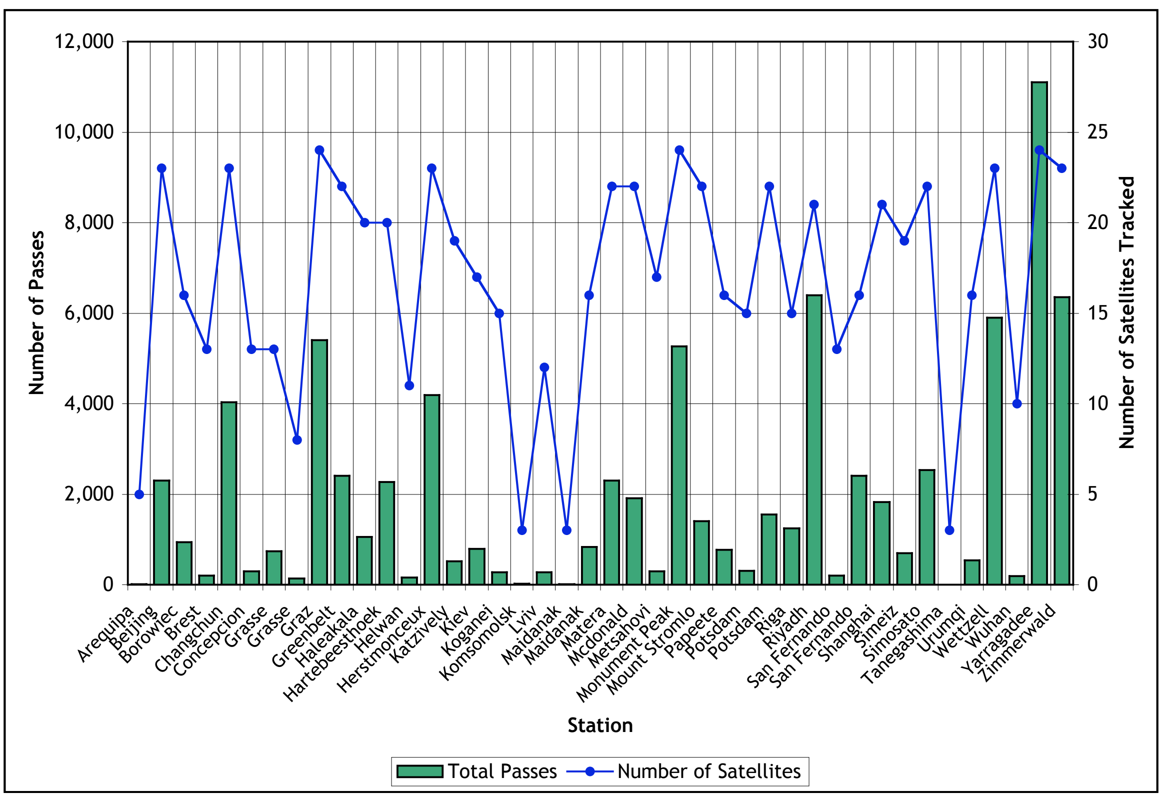
ILRS Quarterly Report Card (Table 2, 04/01/2004-03/31/2005)
(continued)

Site Information		Delft Orbital Analysis				NICT Orbital Analysis				MCC Orbital Analysis				SHAO Orbital Analysis			
Station Location	Station Number	NP RMS	short term (mm)	long term (mm)	% good LAG. NP	NP RMS	short term (mm)	long term (mm)	% good LAG. NP	NP RMS	short term (mm)	long term (mm)	% good LAG. NP	NP RMS	short term (mm)	long term (mm)	% good LAG. NP
Baseline		10.0	20.0	20.0	95	10.0	20.0	20.0	95	10.0	20.0	20.0	95	10.0	20.0	20.0	95
Yarragadee	7090	8.7	10.2	5.3	100.0	1.9	22.6	13.1	100.0	2.0	16.0	4.1	97.7	2.0	15.6	5.0	95.5
Riyadh	7832	11.2	14.0	3.2	99.9	3.1	25.9	9.1	100.0	3.8	37.4	23.0	96.9	3.4	28.1	17.9	96.1
Zimmerwald	7810	9.3	12.3	4.2	100.0	2.3	14.7	9.9	100.0	2.7	8.0	3.2	93.8	2.2	14.1	8.0	94.6
Graz	7839	8.4	9.4	2.0	100.0	1.1	13.0	5.6	100.0	2.1	7.9	3.6	100.0	1.7	15.1	2.1	96.0
Wettzell	8834	11.4	20.4	10.6	99.7	2.5	23.1	15.7	100.0	2.6	13.1	9.5	96.4	2.7	21.5	11.5	95.7
Monument_P	7110	10.6	18.2	3.1	100.0	2.6	24.6	12.5	99.5	2.4	13.3	1.7	94.8	2.3	20.0	3.0	95.1
Herstmonce	7840	10.0	13.1	4.5	100.0	1.9	15.3	3.9	100.0	2.5	12.1	3.8	97.9	2.3	15.8	2.9	94.3
Changchun	7237	24.3	38.0	14.1	100.0	9.8	41.3	13.9	100.0	5.3	31.1	16.9	80.7	7.0	30.6	18.9	94.1
Mount_Stro	7825	12.0	16.4	1.7	99.5	3.3	22.4	14.6	99.9	4.0	16.0		91.2				
San_Fernan	7824	38.7	56.5	53.2	100.0	3.6	28.2	20.5	100.0	3.3	23.0	4.5	96.1	4.8	35.6	24.1	98.7
Simosato	7838	30.7	32.9	21.7	99.9	3.8	34.5	21.6	99.7	4.5	20.6	10.7	84.0	5.1	17.3	5.5	95.2
Matera	7941	9.1	14.2	3.5	99.5	2.1	27.8	5.5	99.6	2.6	14.7	4.4	97.2				
Greenbelt	7105	10.4	13.2	5.2	100.0	2.0	26.0	12.6	100.0	2.4	15.0	3.4	97.2	2.5	11.5	6.0	95.9
Hartebeest	7501	11.7	15.2	9.7	99.7	2.5	27.2	7.5	100.0	2.4	14.0	4.8	97.0	2.7	25.6	10.2	95.7
Beijing	7249	18.1	19.5	8.6	99.3	13.2	26.4	10.7	99.4	8.2	52.8	29.4	83.6	7.3	33.6	17.6	93.5
McDonald	7080	12.5	19.4	5.1	100.0	2.5	21.2	8.6	100.0	2.6	10.7	4.3	97.5	2.3	15.1	7.0	95.7
Shanghai	7837	15.9	20.1	12.2	98.6	6.6	21.4	12.8	100.0	5.7	12.1	14.4	90.8	5.8	18.9	20.2	94.6
Potsdam	7841	10.2	10.8	2.7	98.0	4.1	28.7	15.8	100.0	3.0	10.1	4.5	91.7				
Riga	1884	43.7	48.5	24.1	100.0	5.6	53.9	28.0	100.0	5.8	60.1	32.3	94.0				
Grasse	7835	12.2	14.4	7.6	100.0	1.5	22.9	8.6	100.0	2.5	29.3	23.3	96.0	1.4	22.7	8.0	95.3
Borowiec	7811	24.7	30.3	16.1	100.0	5.1	30.7	14.9	100.0	4.8	20.8	13.3	85.0	5.5	20.5	14.2	97.8
Kiev	1824	64.8	30.6	20.4	100.0												
Maidanak	1864	72.8	51.7	25.7	100.0												
Lviv	1831					15.8	51.4		100.0								
Concepcion	7405	11.7	26.2		100.0	2.9	34.6	32.9	100.0	3.3	23.0		94.9				
Koganei	7308	30.4	30.5		100.0	5.2	31.2		100.0	3.8	21.7		89.5	3.6	26.1		93.2

Total Pass Segments by Satellite in 2004



Total Pass Segments by Station in 2004



Lunar Tracking Statistics (2004)

Site	Station	Number of Pass Segments	Number of Passes
McDonald	7080	56	31
Grasse	7845	450	55
Matera	7941	9	3

Low Elevation Tracking Statistics (2004)

		Number of Normal Point Observations At or Below 10 Degrees Elevation			
Site	Station	LAGEOS-1	LAGEOS-2	Etalon-1	Etalon-2
Borowiec	7811	20	3	0	0
Grasse	7845	12	4	0	0
Graz	7839	10		0	0
Shanghai	7837		12	0	0
Wettzell	8834	4		0	0

CoM Website "Front Page"

SLR Satellite Center-of-Mass Offset Information

http://ilrs.gsfc.nasa.gov/satellite_missions/center_of_ma

ILRS Home → Satellite Missions → SLR Satellite Center-of-Mass Offsent Information → SLR Satellite Center-of-Mass Offset Information

SLR Satellite Center-of-Mass Offset Information

SLR Satellite Center-of-Mass Concept

SLR Satellite Center-of-Mass (CoM) Offset Information

LRA Center-of-Mass Offset Concept Description

Satellite	Size of Array	Number of Reflectors	Body fixed coordinates of array phase center w.r.t. satellite CoM (mm)	spacecraft coordinate definition	CoM Correction (mm) and details
ADEOS-1	35.6 cm edge hollow cube	1	?	?	
ADEOS-2	16 cm diameter hemisphere	9	(+5000, +1050, +500)	Y-axis anti-parallel with velocity, Z-axis away from nadir	details
AJISAI	214 cm diameter sphere	1,436	1028	sphere: radius of phase center of each cube	details
Beacon-C	Pyramidal array on nadir face	160	?	phase center of each cube	
CHAMP	5cm diameter, 45 deg pyramid	4	(0, 0, 250)	Z-axis towards nadir	details
Envisat	20 cm diameter hemisphere	9	(-4920, +1350, -1180)	X-axis direction of satellite pitch, Z-axis away from nadir	details
ERS2	20 cm diameter hemisphere	9	(1000, -710, -1010)	X-axis direction of satellite pitch, Z-axis away from nadir	
ETALON 1 & 2	129.4 cm diameter sphere	2,134	614	sphere: radius of phase center of each cube	details
GFO1	16 cm diameter hemisphere	9	(+182, +753, +599)	Y-axis anti-parallel with velocity, Z-axis away from nadir	details
GFZ1	20 cm diameter sphere	60		sphere: radius of phase center of each cube	58 +/- 2
GLONASS	120x120 cm planar array	396	(-1542, 0, 0)	X-axis away from nadir, Y-axis towards Sun	
GLONASS	66x66 cm planar array	132	(-1542, 0, 0)	X-axis away from nadir, Y-axis towards Sun	
GLONASS	66x66 cm planar array	124	(-1522, 0, 0)	X-axis away from nadir, Y-axis towards Sun	
GPS 35 and 36	23.9x19.4 cm planar array	32	(862.6, -524.5, 658.4)	Z-axis towards nadir	
GRACE-A/-B	5cm diameter, 45 deg pyramid	4	(0, 0, 250)	Z-axis towards nadir	details soon
Gravity Probe B	Open hemisphere	9	(0, 0, -1820)	+Z-axis towards RA 343.26deg, DEC 16.84deg	details
ICESat	16 cm diameter hemisphere	9	?	X-axis towards satellite Zenith, Y-axis along solar panel	details
JASON-1	hemisphere	9	(236, 598, 683)	X-axis in direction of velocity, Z-axis towards nadir	details
LAGEOS-1	60 cm diameter sphere	426	258	sphere: radius of phase center of each cube	details
LAGEOS-2	60 cm diameter sphere	426	258	sphere: radius of phase center of each cube	details
Larets	20 cm diameter sphere	60	58	sphere: radius of phase center of each cube	58 +/- 2
LRE	quasi-spherical, 47x51 cm diameter	126		sphere: radius of phase center of each cube	210 details
Meteor-3M	spherical ball, 6 cm diameter	1	(+113, +475.7, +2101.5)	?	details
Starlette	24 cm diameter sphere	60		sphere: radius of phase center of each cube	75
Stella	24 cm diameter sphere	60		sphere: radius of phase center of each cube	75
TOPEX/Poseidon	150 cm diameter annulus	192	(+1079, +418, +827)	Center of annulus. X-axis in direction of velocity, Z-axis towards nadir	details

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Last modified date: Friday, March 11, 2005
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Maintained by: Carey Noll

International Laser Ranging Service

CoM Website Details (LAGEOS)

LAGEOS-1, 2

http://ilrs.gsfc.nasa.gov/satellite_missions/list_of_satellit

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http://igscb.jpl.nasa.gov... | INDIGO | LAGEOS-1, 2

Gravity Probe B
ICESAT
Jason-1
LAGEOS-1, -2
Larets
LRE
LUNAR
Meteor-2-21/Fizeau
Meteor-3-6
Meteor-3M
MSTI-2
REFLECTOR
RESURS-01-3
Seasat
Starlette, Stella
Sunsat
TiPS, ATEx
TOPEX
VCL
WESTPAC-1
Zeya

studies of reflectivity and satellite orientation.

Mission Parameters:

LAGEOS Parameters

	LAGEOS-1	LAGEOS-2
Sponsor:	United States	United States & Italy
Expected Life:	many decades	many decades
Primary Applications:	geodesy	geodesy
COSPAR ID:	7603901	9207002
SIC Code:	1155	5986
NORAD SSC Code:	8820	22195
Launch Date:	May 4, 1976	October 22, 1992
RRA Diameter:	60 cm	60 cm
RRA Shape:	sphere	sphere
Reflectors:	426 corner cubes	426 corner cubes
Orbit:	circular	circular
Inclination:	109.84 degrees	52.64 degrees
Eccentricity:	0.0045	0.0135
Perigee:	5,860 km	5,620 km
Period:	225 minutes	223 minutes
Weight:	406.965 Kg	405.38 kg

Center of Mass Information:

ref: Otsubo and Appleby, "System-dependent centre-of-mass correction for spherical geodetic satellites" Journal of Geophysical Research, 108, B4, 2201, doi:10.1029/2002JB002209, 2003.

The *standard* LAGEOS center-of-mass correction is 251 mm

correction for single photon systems

edit level	com (mm)
none	242
3.0	245
2.5	247
2.0	250

correction for C-SPAD (mm)

FWHM pulse width (ps)	edit level	ave. num detected photons 0.1	1	10	100
1	3.0	245	249	256	257
	2.5	247	250	256	257
	2.0	250	251	256	257
100	3.0	245	247	251	252
	2.5	246	248	251	252
	2.0	249	249	251	252

correction for leading-edge-half maximum systems (mm)

FWHM pulse width (ps)	com (mm)
1	256
100	252
300	248
1000	244
3000	243

Additional information:

LAGEOS (NASA Spacelink)
LAGEOS Investigations
LAGEOS Spin Axis Analysis
LAGEOS Analysis Reports
LAGEOS once per revolution force

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