The contribution of LARES in future ITRF developments

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NASA Goddard 698

2nd International LARES Science Workshop
Roma, Italy, 17-19 September, 2012

December 1972—Vol. 20, No. 9

goddard news

SAS-B in Orbit from Africa

Goddard's Small Astronomy Satellite-B, carrying the most advanced gamma ray telescope ever orbited, was lofted into the starry African sky early on November 16 from the San Marco Equatorial Range in the Indian Ocean off the coast of Kenya.

In describing the launch, the first night lift-off from the range, the Nairobi *Daily Nation* reported, "Jubilant Italian, American and Kenyan personnel manning the Santa Rita off-shore control platform and the Ngomeni base camp watched in wonder as the fiery projectile soared into the night sky. . . ."

For the SAS team headed by Mrs. Marjorie R. Townsend, Project Manager, and Dr. Carl Fichtel, Project Scientist, the success holds the promise of scientific discoveries in the field of gamma-radiation comparable to those pioneered for X-ray astronomy by the first SAS "Uhuru." That satellite was launched December 12, 1970, from San Marco.

The SAS-B launch was a milestone for the Scout rocket team and marked its 26th consecutive successful launch to set a new record for the U.S. space program.

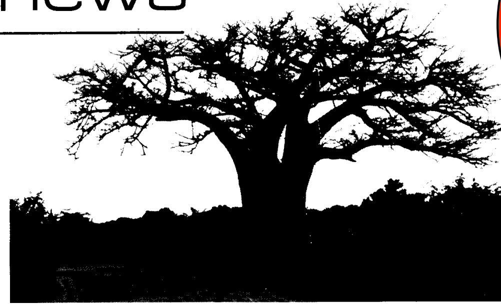
As the *Goddard News* goes to press, SAS-B, officially named Explorer 48, is already sending back scientific data from its orbit high over the earth's equator. The unique 32-level digitized spark chamber gamma ray telescope, designed and built at Goddard, is already undertaking an "all-sky" survey of celestial gamma rays to determine their intensity, energy and direction of arrival.

Dr. Fichtel says, "In the next few weeks we should have the data to resolve the current questions on the nature of the gamma radiation from the galactic center region. From there, we hope to go on to study the dynamics of the galactic plane, point sources including supernovae, and extragalactic gamma radiation."

Gamma ray astronomy, a relatively new field, was given high priority by the Space Science Board of the National Research Council last year. Scientists at Goddard's Laboratory for High Energy Astrophysics are anxious to know more about celestial gamma radiation in order to obtain a better understanding of some of the major energy transfers going on in the universe.

SAS-B should provide many of those insights.

(See Page 2)



HUGE AFRICAN BAOBAB TREE on dirt road to Base Camp. The road, sandy and pitted with chuck holes, proved to be a challenge to SAS project members, most of whom lived in hotels at Malindi, 17 miles south of Base Camp.

BEING HOISTED ABOARD the Santa Rita platform in a Billy Pugh net is one of the memorable experiences at the San Marco Equatorial Range. The Italian crane operator says he's never lost a passenger.

RELAXED ATMOSPHERE PREVAILED during the 12-hour, almost trouble-free SAS-B/Scout countdown. In foreground (left), Professor Luigi Broglio, Director of the Italian Aerospace Research Center, talks with Professor Michele Sirinian, San Marco launch director. In background (right) is Dr. Carl Fichtel, SAS-B Project Scientist, along with Mrs. Townsend and John Bosworth.

Happy Holidays

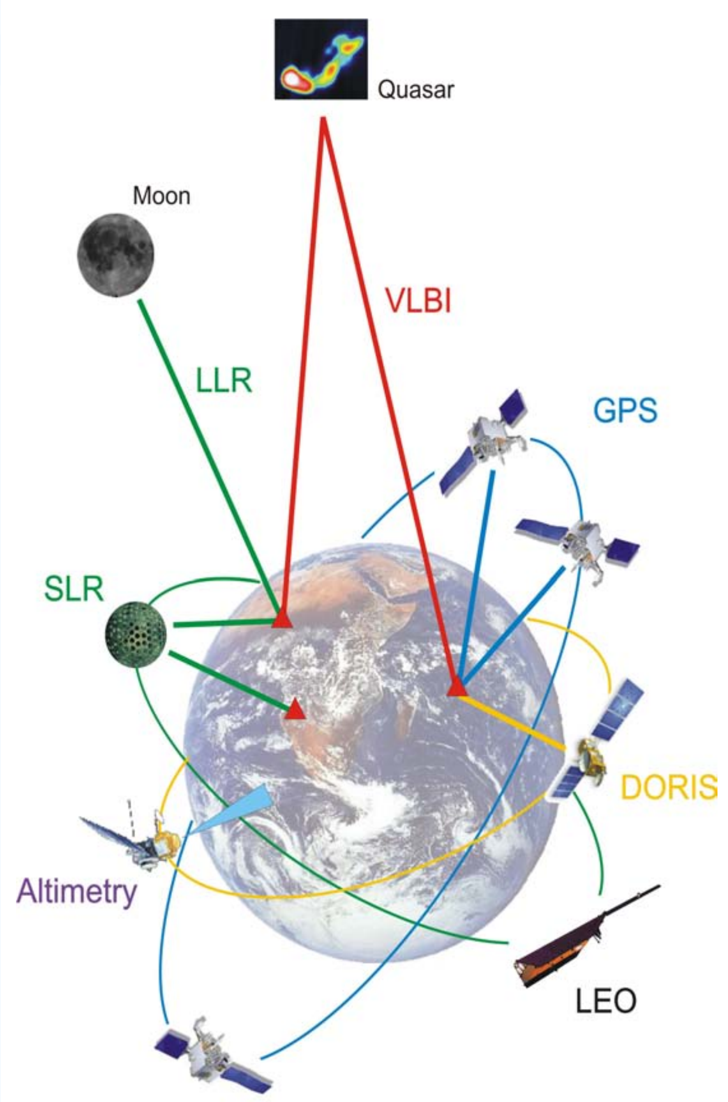
SAS PROJECT MANAGER, Mrs. Marjorie R. Townsend and SAS-B Spacecraft Manager, John M. Bosworth, in Santa Rita Control Center during countdown.

John M. Bosworth
SAS-B
S/C Manager
&
ILRS 1st Director

RELAXED ATMOSPHERE PREVAILED during the 12-hour, almost trouble-free SAS-B/Scout countdown. In foreground (left), Professor Luigi Broglio, Director of the Italian Aerospace Research Center, talks with Professor Michele Sirinian, San Marco launch director. In background (right) is Dr. Carl Fichtel, SAS-B Project Scientist, along with Mrs. Townsend and John Bosworth.

GGOS: Technique Integration for the ITRF

- **GGOS**: Global Geodetic Observing System
- Assure consistency – improve accuracy
- Complementarity adds strength
- Benefit via co-location at sites/on satellites
- Distinguish geophysical signals from systematic errors
- Crucial to separate distinct components and processes in the Earth System (e.g. mass transport)



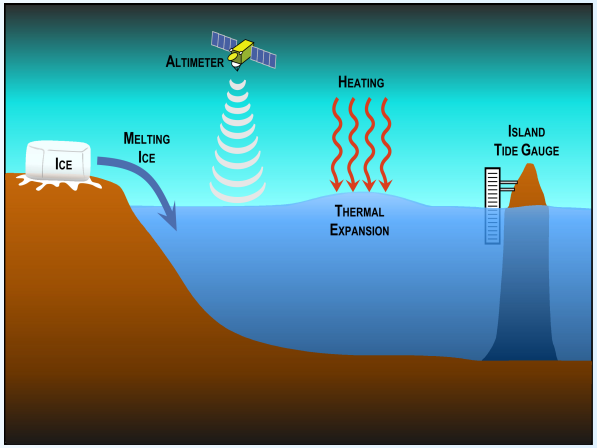
The Geodetic Reference Frame Requirement

<1 mm reference frame accuracy

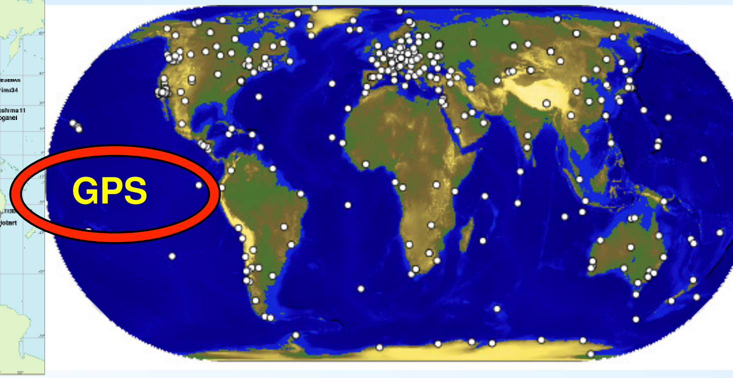
< 0.1 mm/y stability

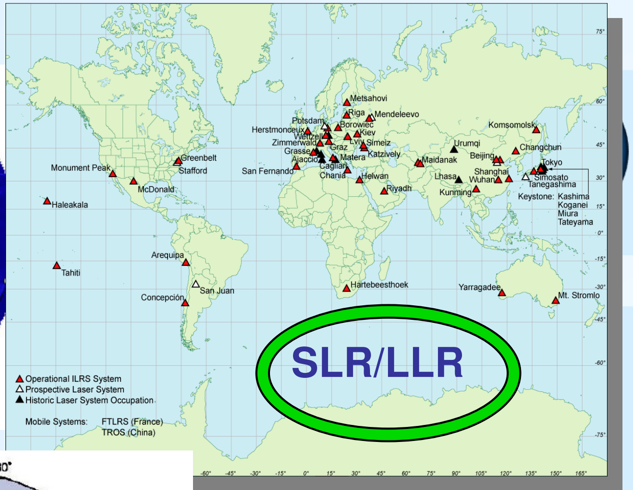
Improvement over current ITRF performance by a factor of 10-20!

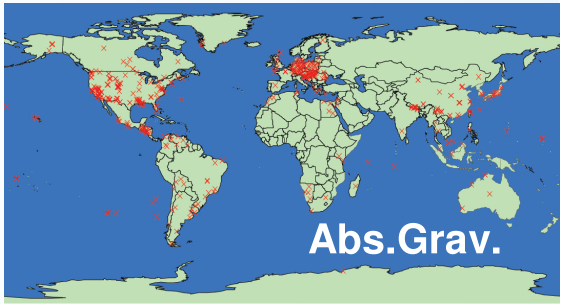
Measurement of sea level change is the primary science driver

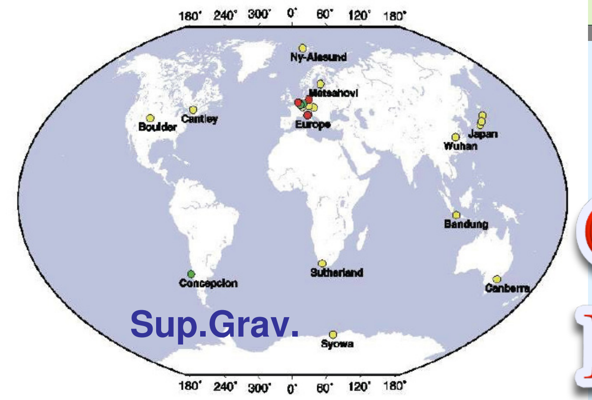


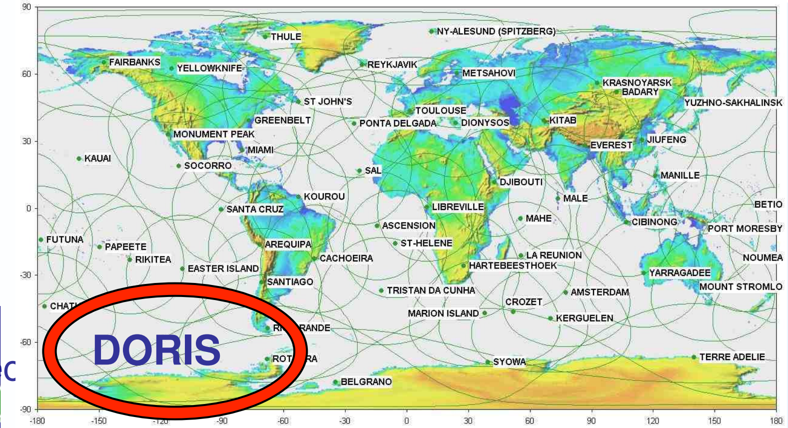
Geodetic Networks











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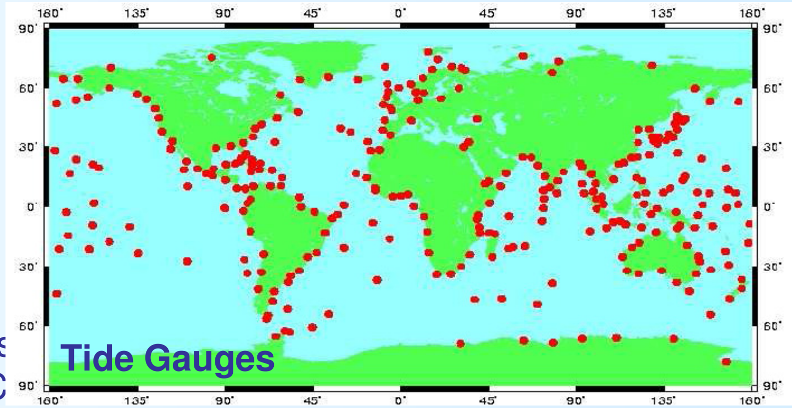
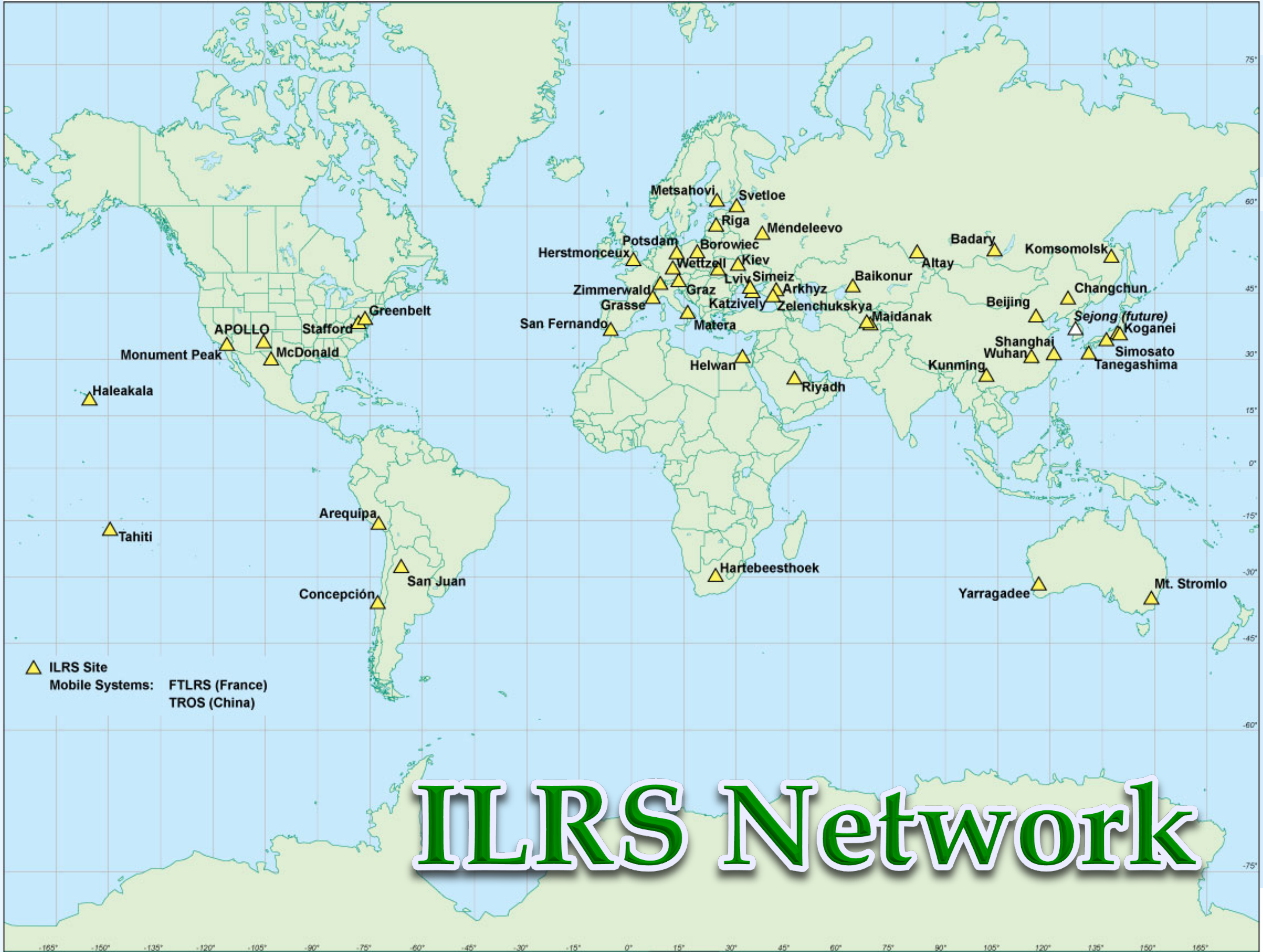
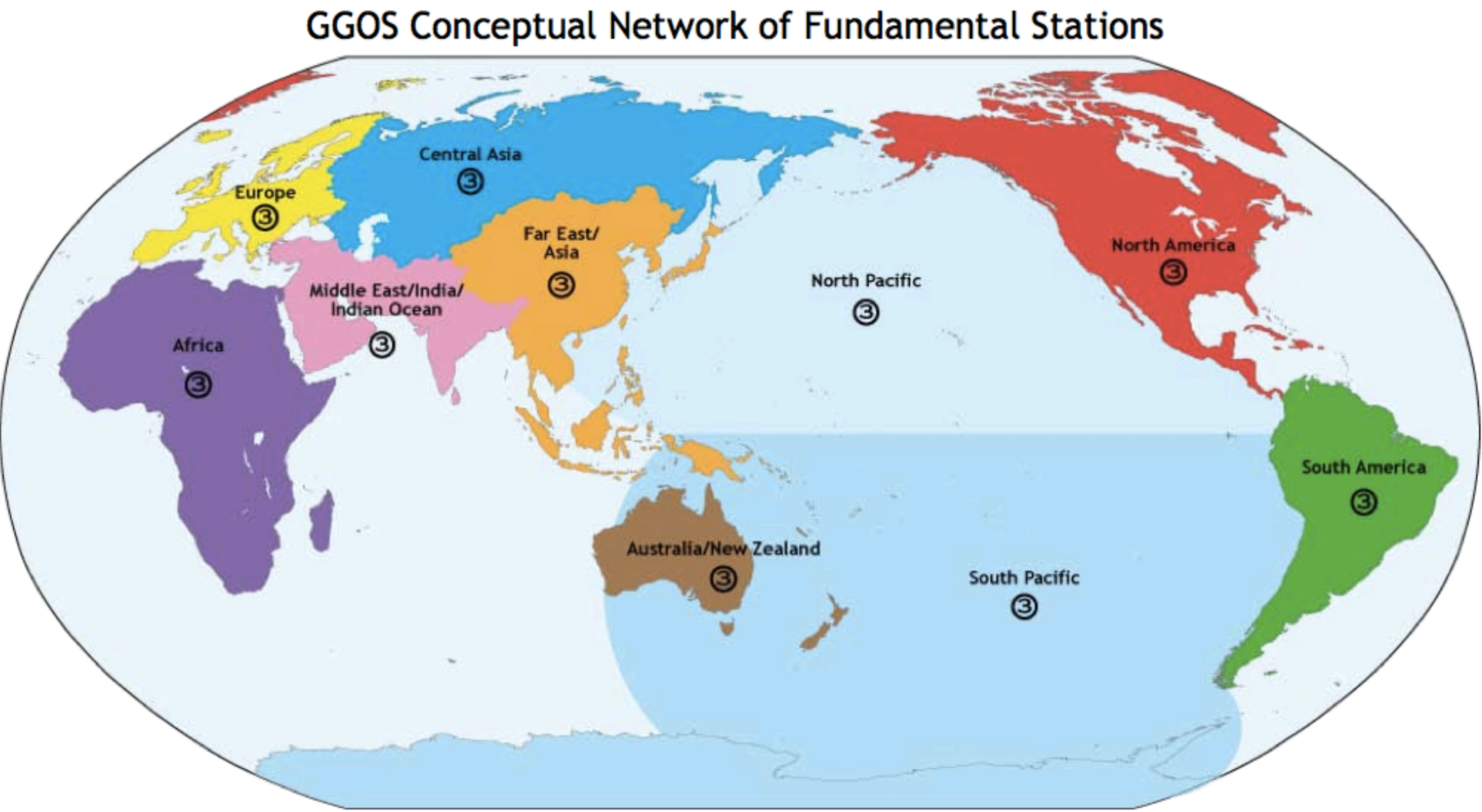



ILRS Network
Metsahovi
Svetloe
Riga
Mendeleevo
Potsdam
Borowiec
Herstmonceux
Wettzell
Kiev
Lviv
Simeiz
Zimmerwald
Graz
Arkhyz
Grasse
Katzively
Zelenchukskya
San Fernando
Matera
Helwan
Riyadh
Baikonur
Maidanak
Altay
Badary
Komsomolsk
Changchun
Beijing
Sejong (future)
Koganei
Shanghai
Wuhan
Simosato
Kunming
Tanegashima
Greenbelt
Stafford
APOLLO
Monument Peak
McDonald
Haleakala
Tahiti
Arequipa
San Juan
Concepción
Hartebeesthoek
Yarragadee
Mt. Stromlo
ILRS Site
Mobile Systems:
FTLRS (France)
TROS (China)

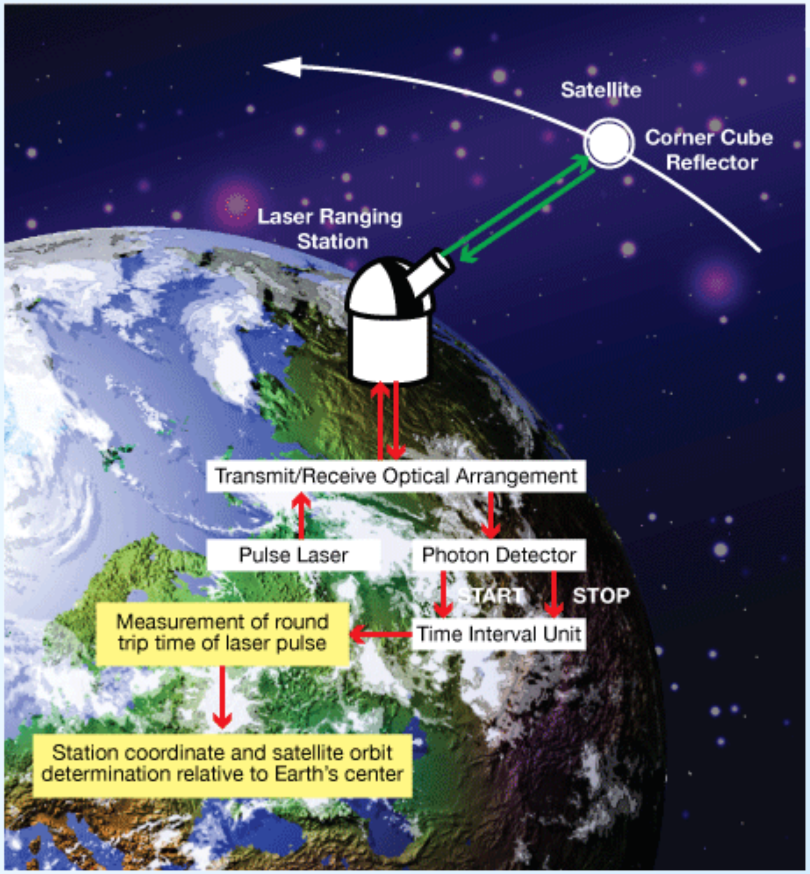
GGOS2020 Core Network



Satellite Laser Ranging - the Technique

Precise range measurement between an SLR station and a satellite using ultra-short laser pulses.

- Simple range measurement
- Space segment is passive
- Simple refraction model
- Night / Day Operation
- Near real-time global data availability
- Satellite altitudes from <300 km to geosynchronous satellites, and the Moon (Mars also with transponders)
- *cm* satellite Orbit Accuracy
- High accuracy and resolution long time series, EOP, $C/S_{n,m}$



- Unambiguous ~ cm accurate orbits
- Long-term stable time series

The Next Generation SLR Systems

The next generation systems will operate with:

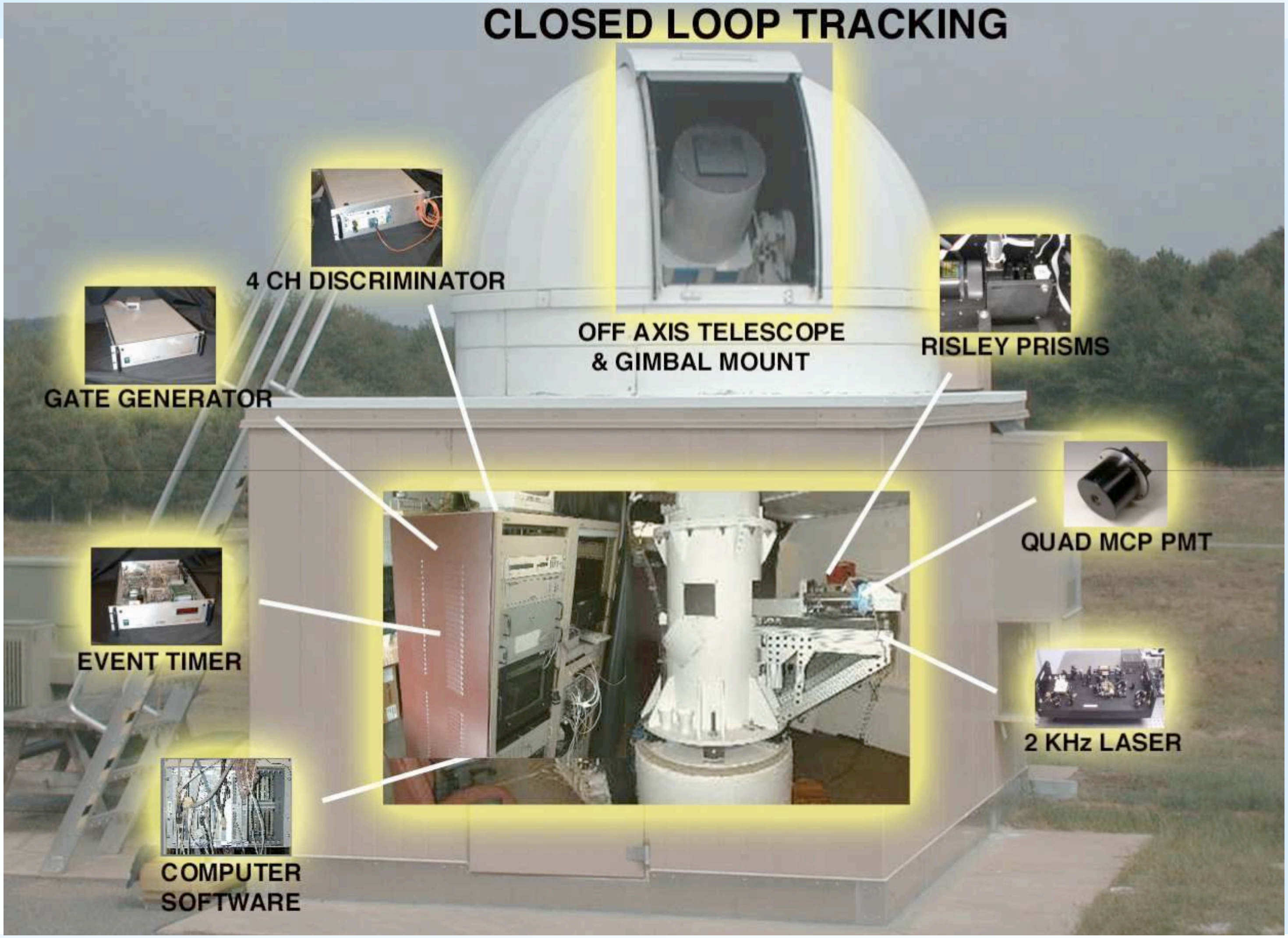
- **higher repetition rate** (100 Hz to 2 kHz) lasers to improve data yield, improve normal point precision, and pass interleaving;
- **photon-counting detectors** to reduce the emitted laser energies by orders of magnitude and reduce optical hazards on the ground and at aircraft (some are totally eye-safe);
- **multi-stop event timers** with few ps resolutions to improve low energy performance in a high solar-noise environment;
- considerably **more automation** to permit remote and even autonomous operation;

Many systems will operate at single photon levels with

- Single Photon Avalanche Diode (SPAD) detectors or
- MicroChannel Plate PhotoMultiplier Tubes (MCP/PMTs).

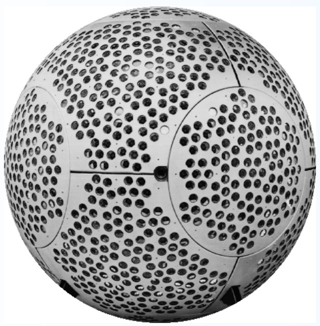
Some systems are experimenting with two-wavelength operations to test atmospheric refraction models and/or to provide unambiguous calibration of the atmospheric delay.

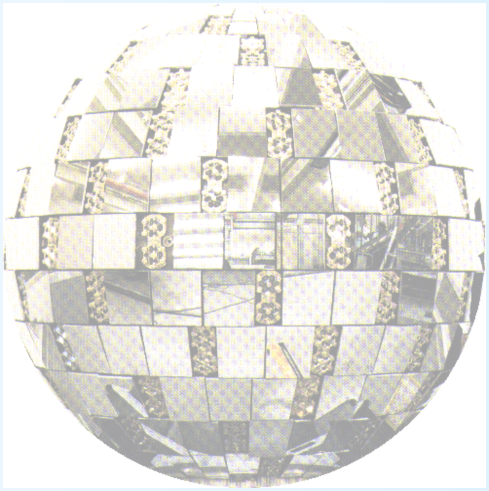
NGSLR Components

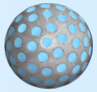


Sample of SLR Satellite Constellation
(Geodetic Satellites)

International Laser Ranging Service



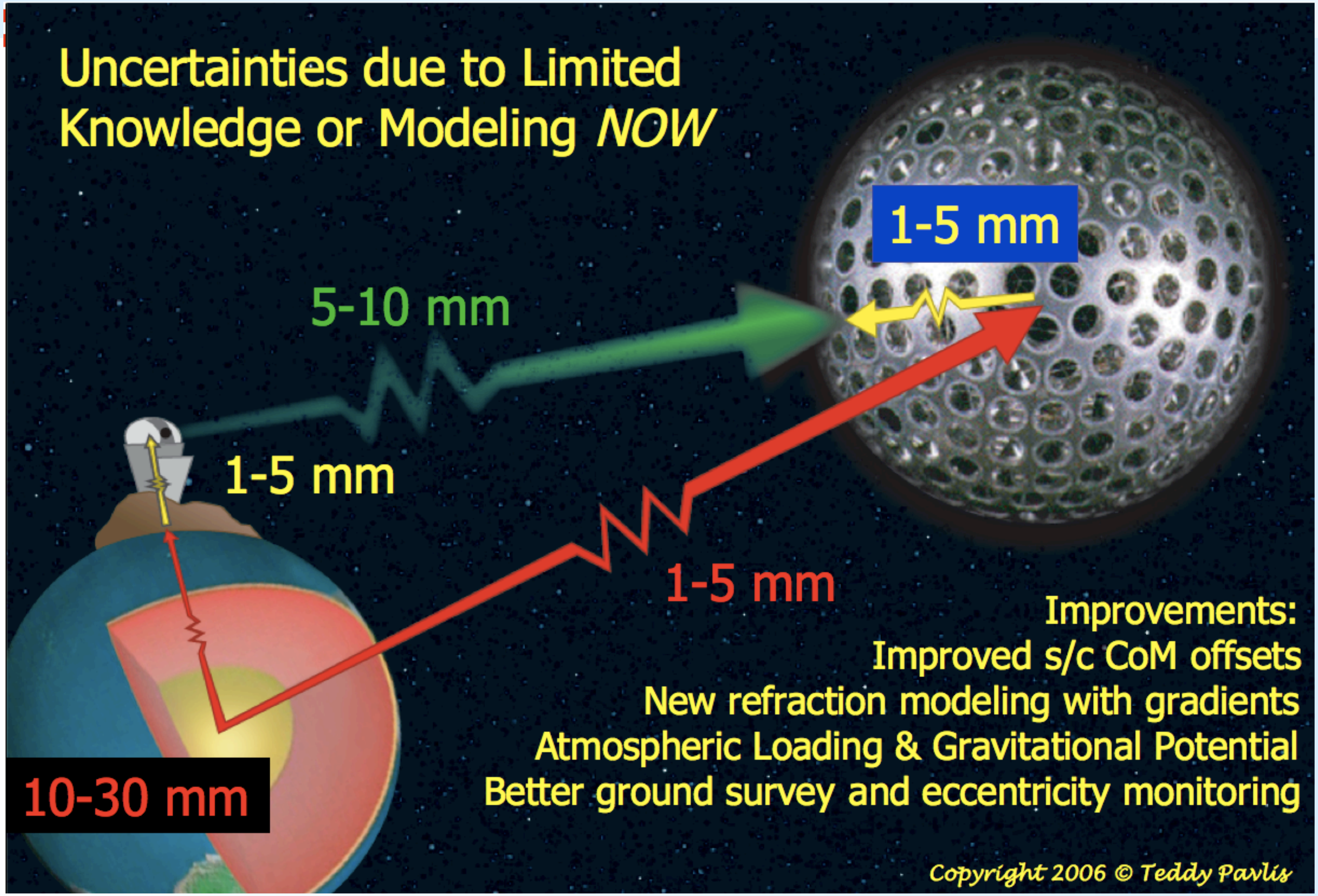



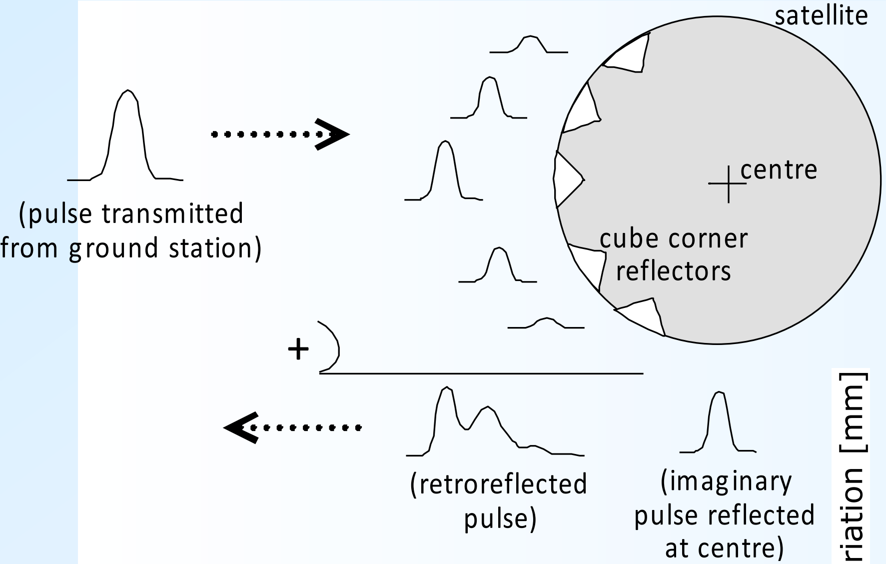
	Etalon-I & -II	LAGEOS-1	LAGEOS-2	Ajisai	Starlette	Stella	LARES
Inclination	64.8°	109.8°	52.6°	50°	50°	98.6°	~70°
Perigee ht. (km)	19,120	5,860	5,620	1,490	810	800	~1500
Diameter (cm)	129.4	60	60	215	24	24	36
Mass (kg)	1415	407	405.4	685	47.3	47.3	~400

LARES $_{A/m}$ = 0.36 x LAGEOS

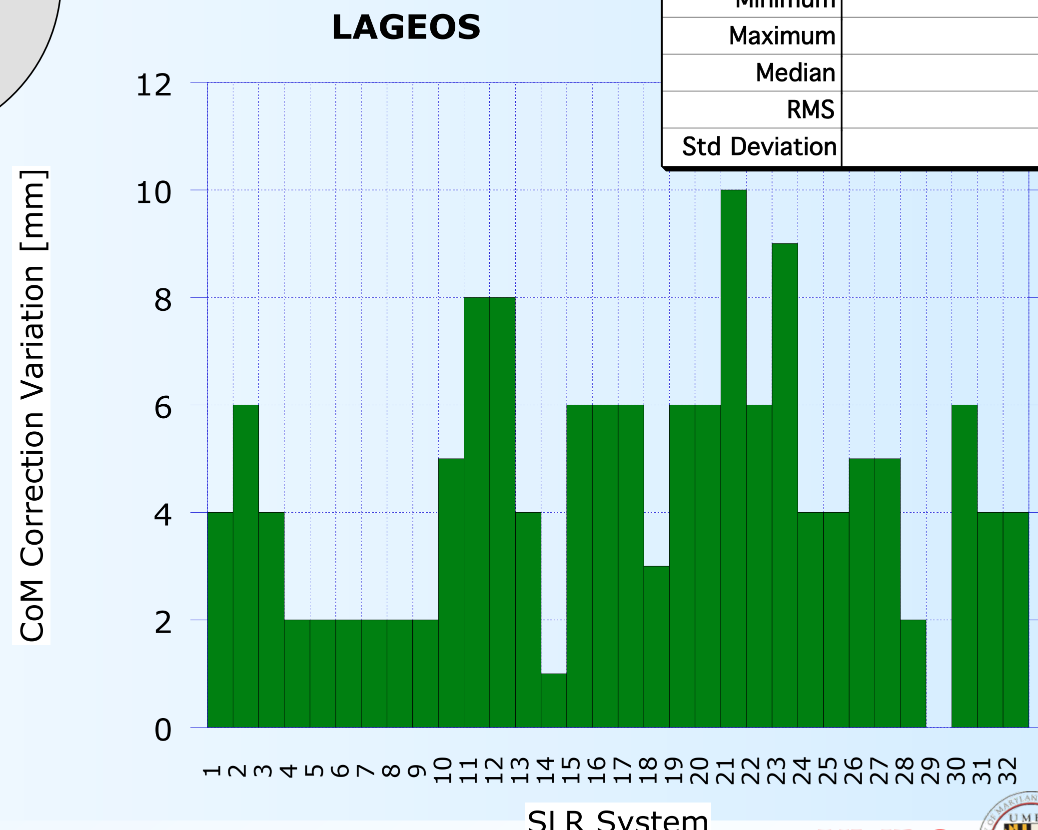
Current SLR Model Status



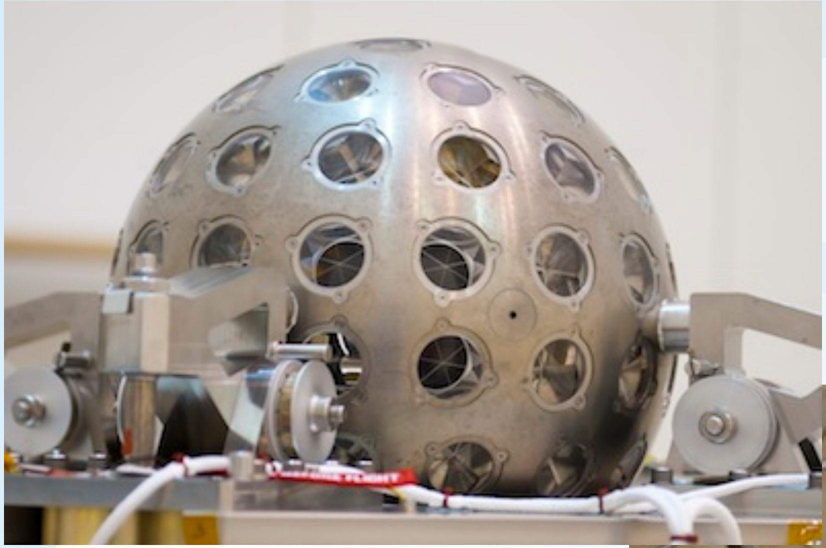
Target Signature (CoM)

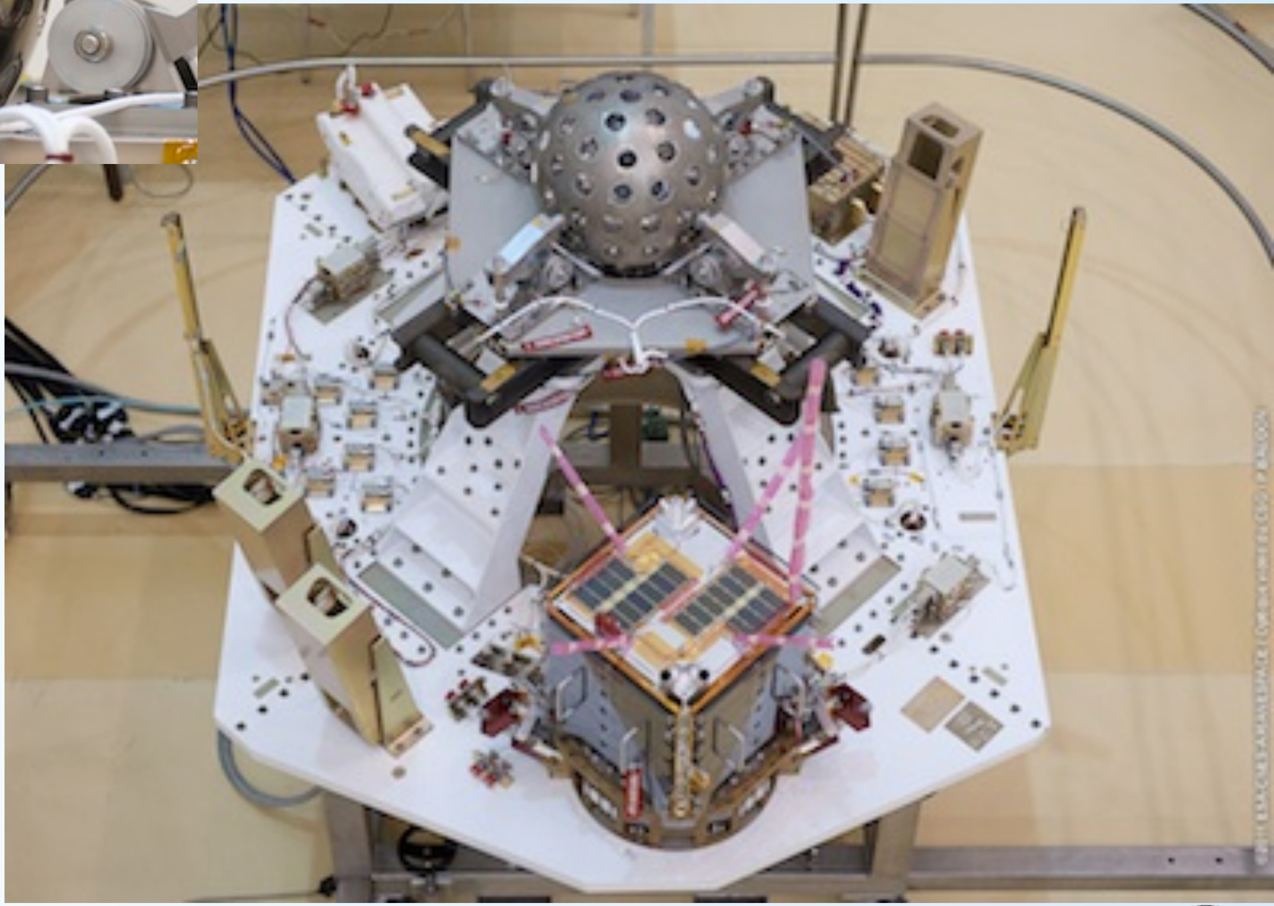


LAGEOS	ΔCoM Range [mm]
Minimum	0
Maximum	10
Median	5
RMS	5
Std Deviation	2



LARES & Other Payloads

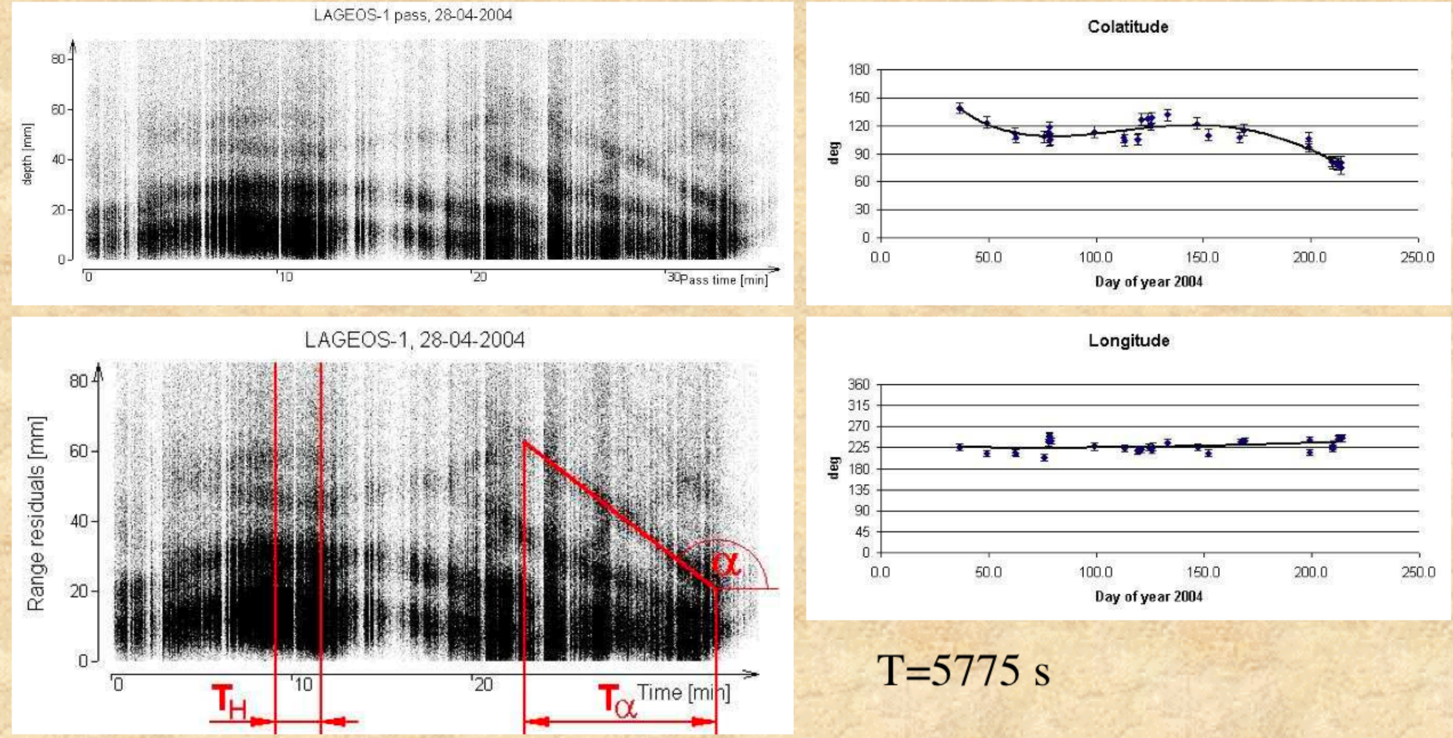




Spin-axis Orientation & Rotation Rate

Spin determination from kHz SLR

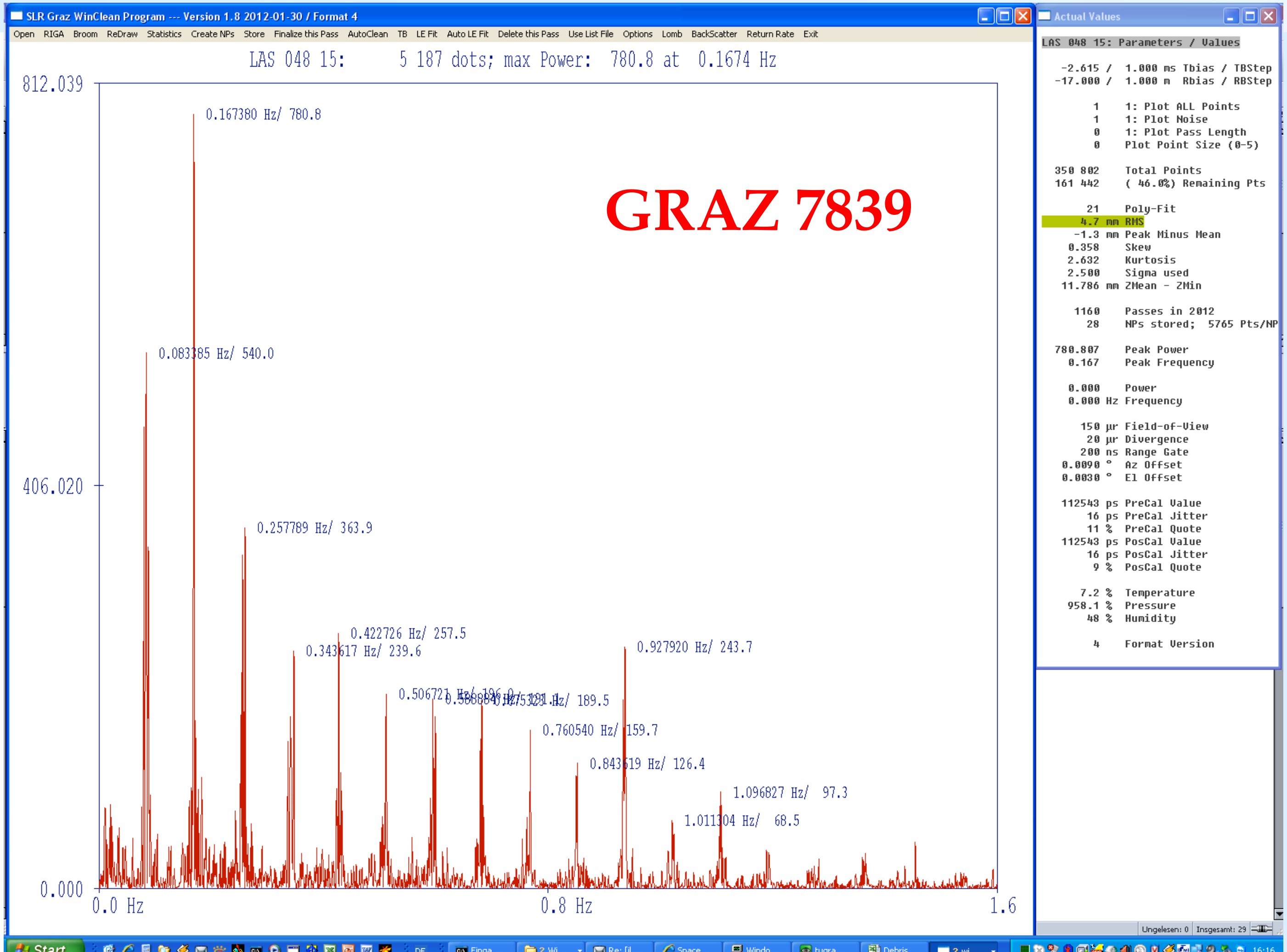
LAGEOS-1



T=5775 s

Kucharski, D., Kirchner, G., Schillak, S., et al. Spin determination of LAGEOS-1 from kHz laser observations. J. Adv. Space Res., 39(10), 1581, doi:10.1016/j.asr.2007.02.045, 2007

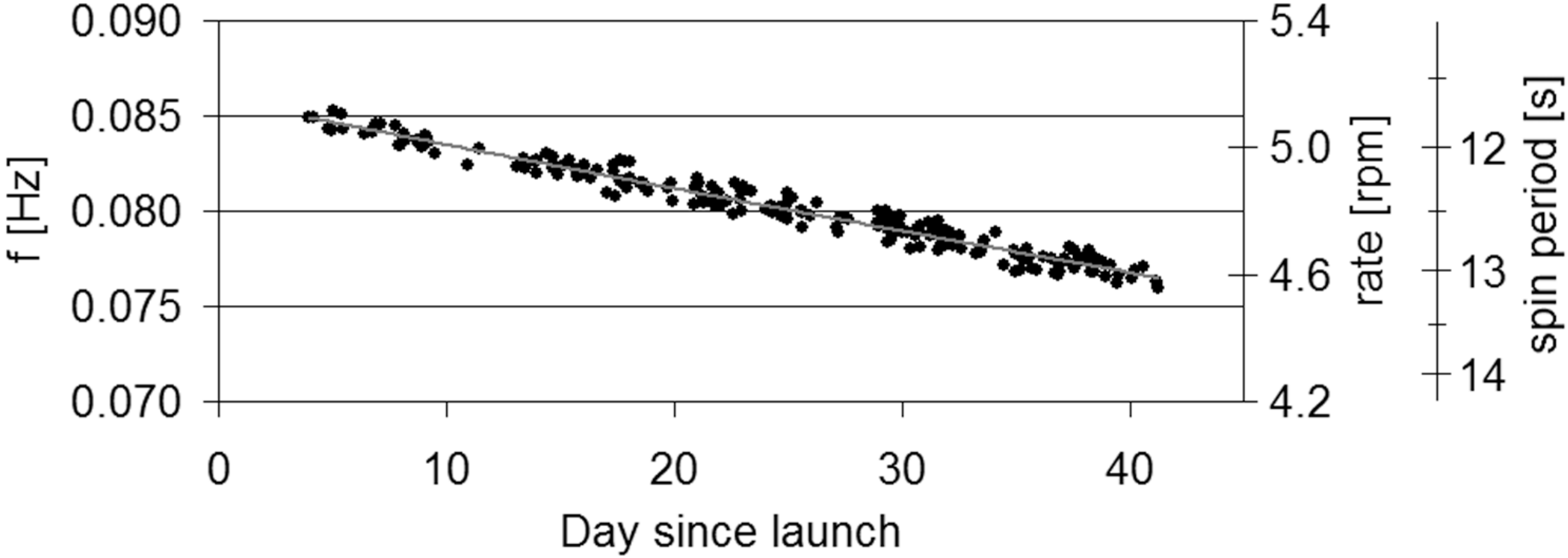
Spectrum of LARES Returns



Spin-axis Orientation & Rotation Rate

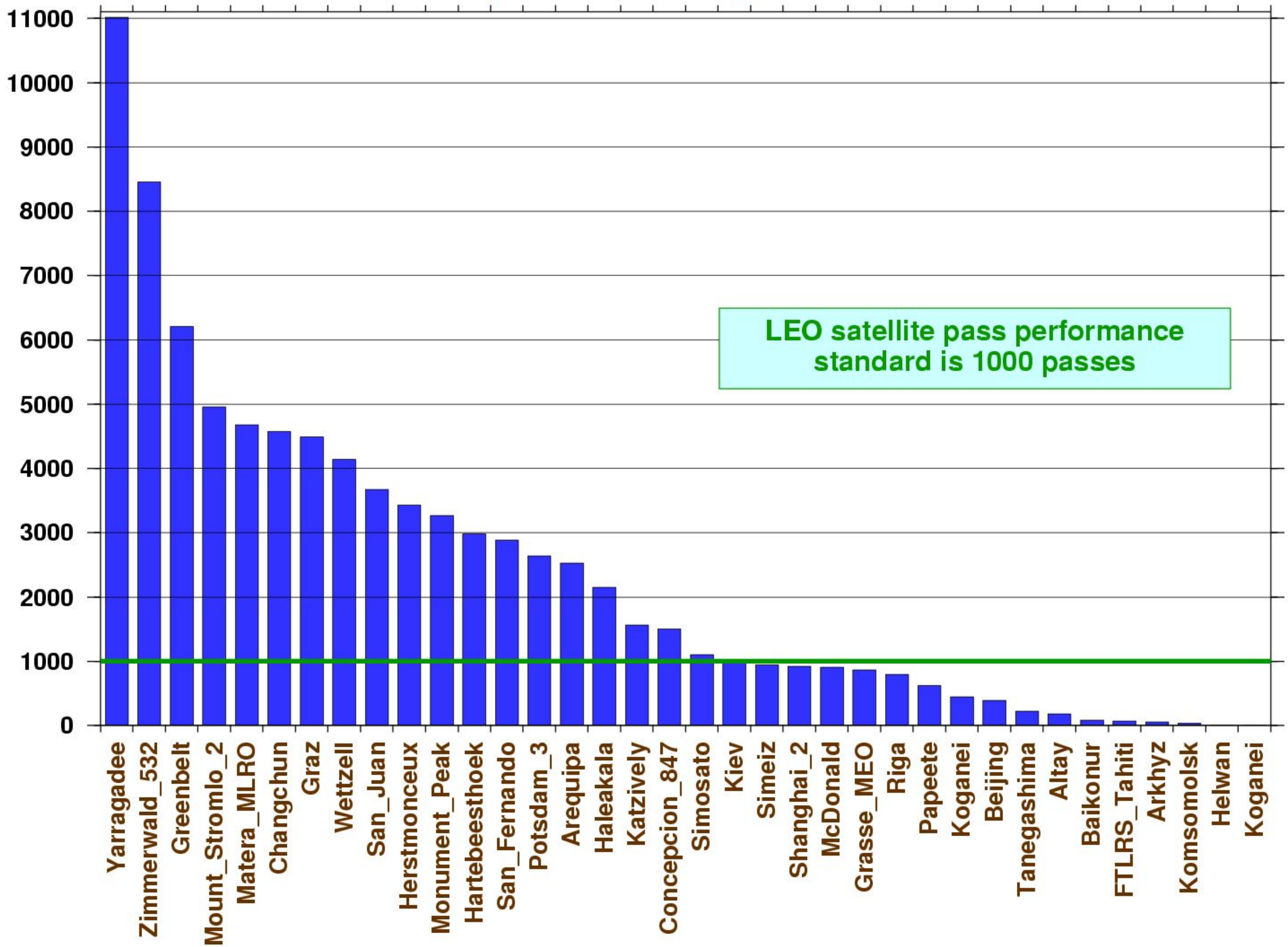
International Laser Ranging Service

LARES inertial spin rate from SLR data from Graz, AT

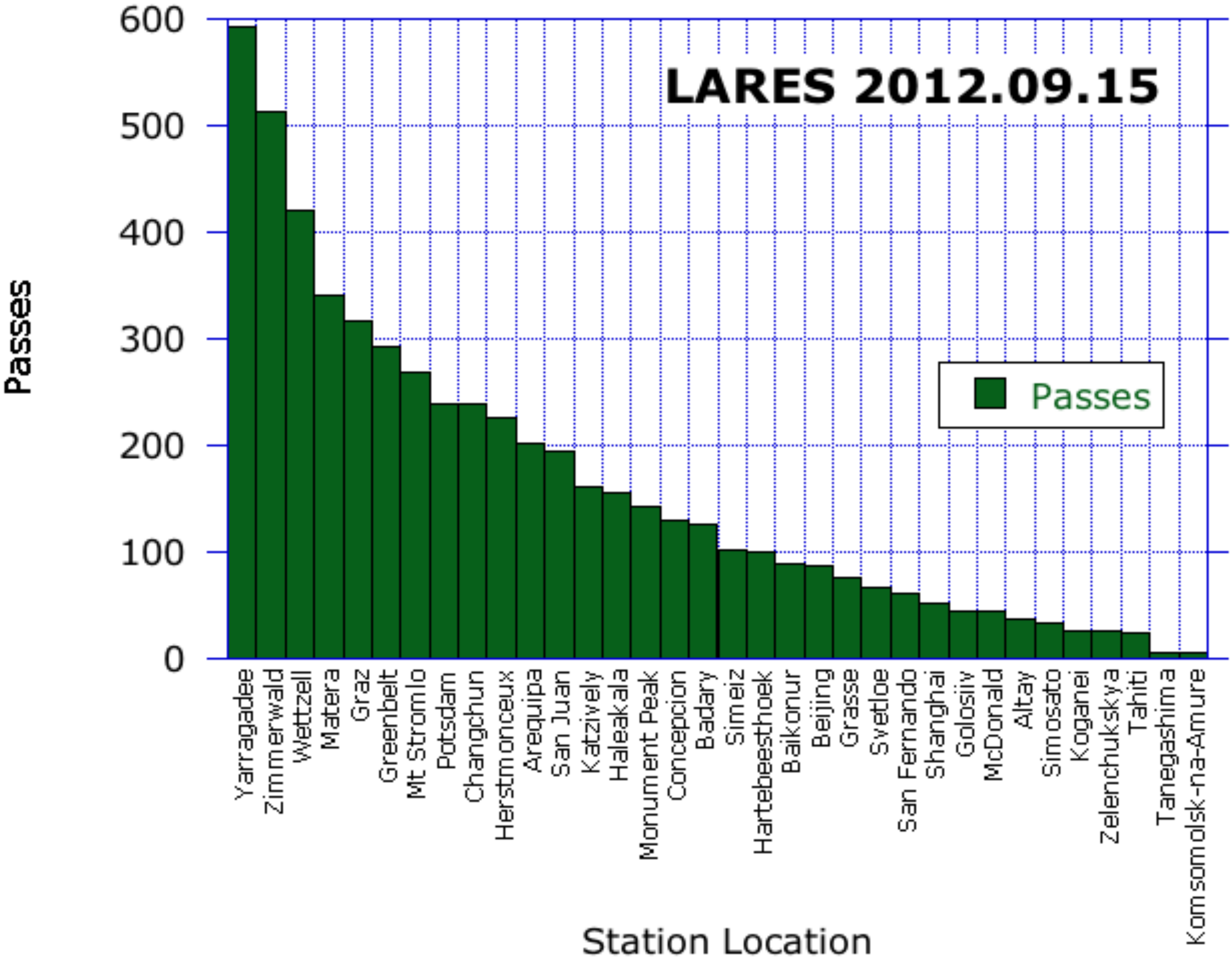


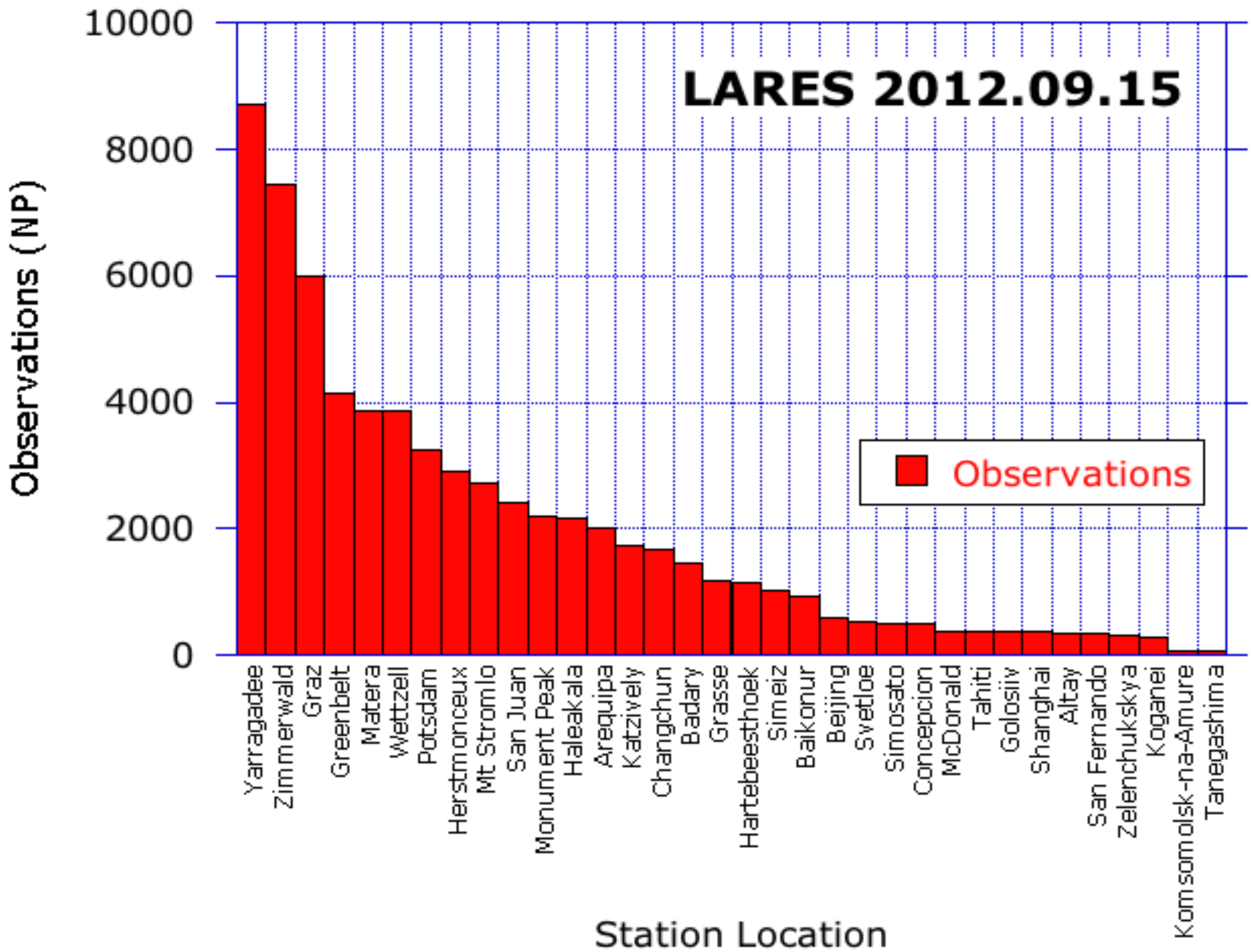
FROM: "Spin rate and spin axis orientation of LARES spectrally determined from Satellite Laser Ranging data", D. Kucharski et al., J. of Adv. In Sp. Res., DOI: 10.1016/j.asr.2012.07.018

LEO passes
from July 1, 2011 through June 30, 2012

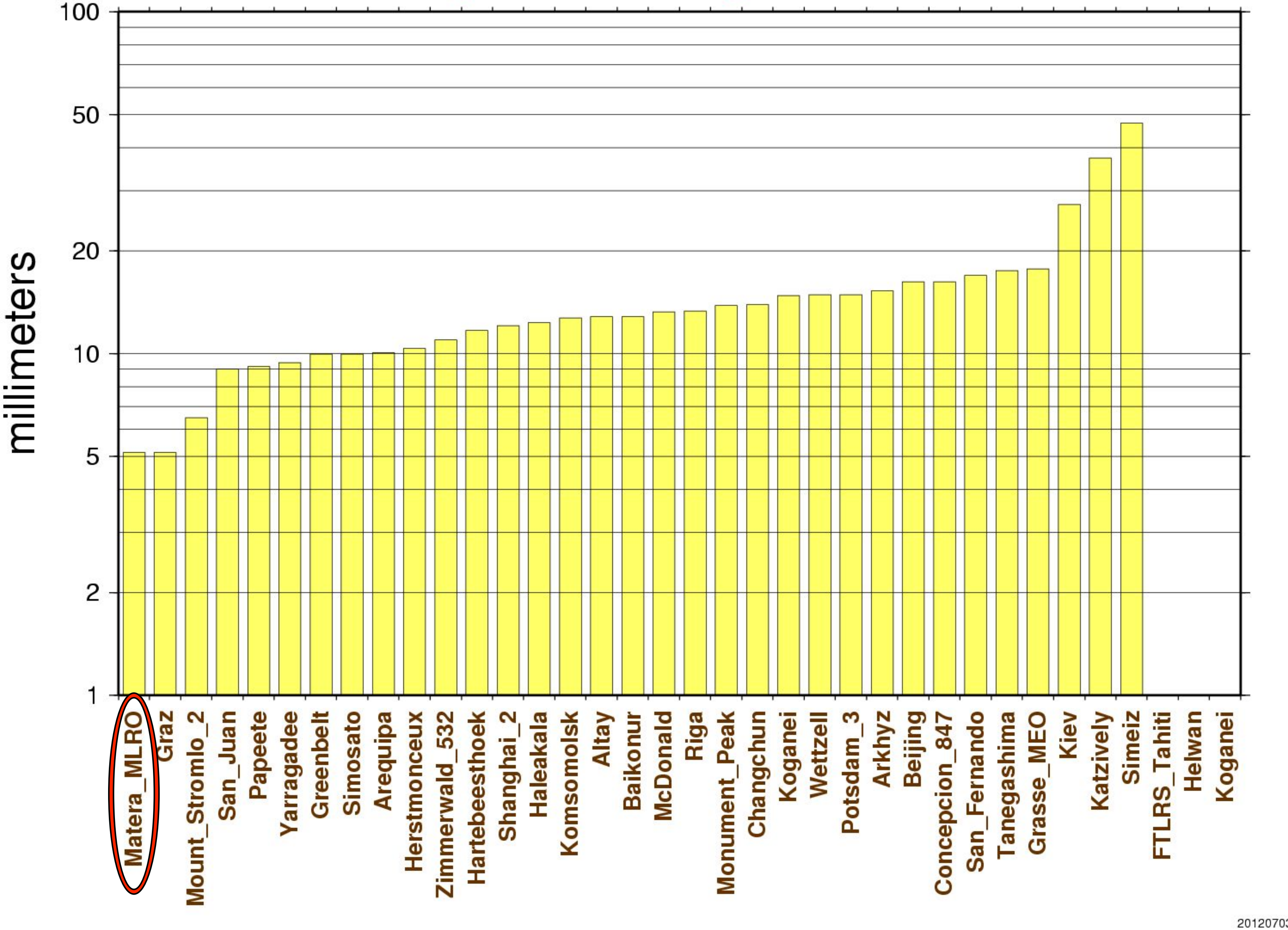


20120703

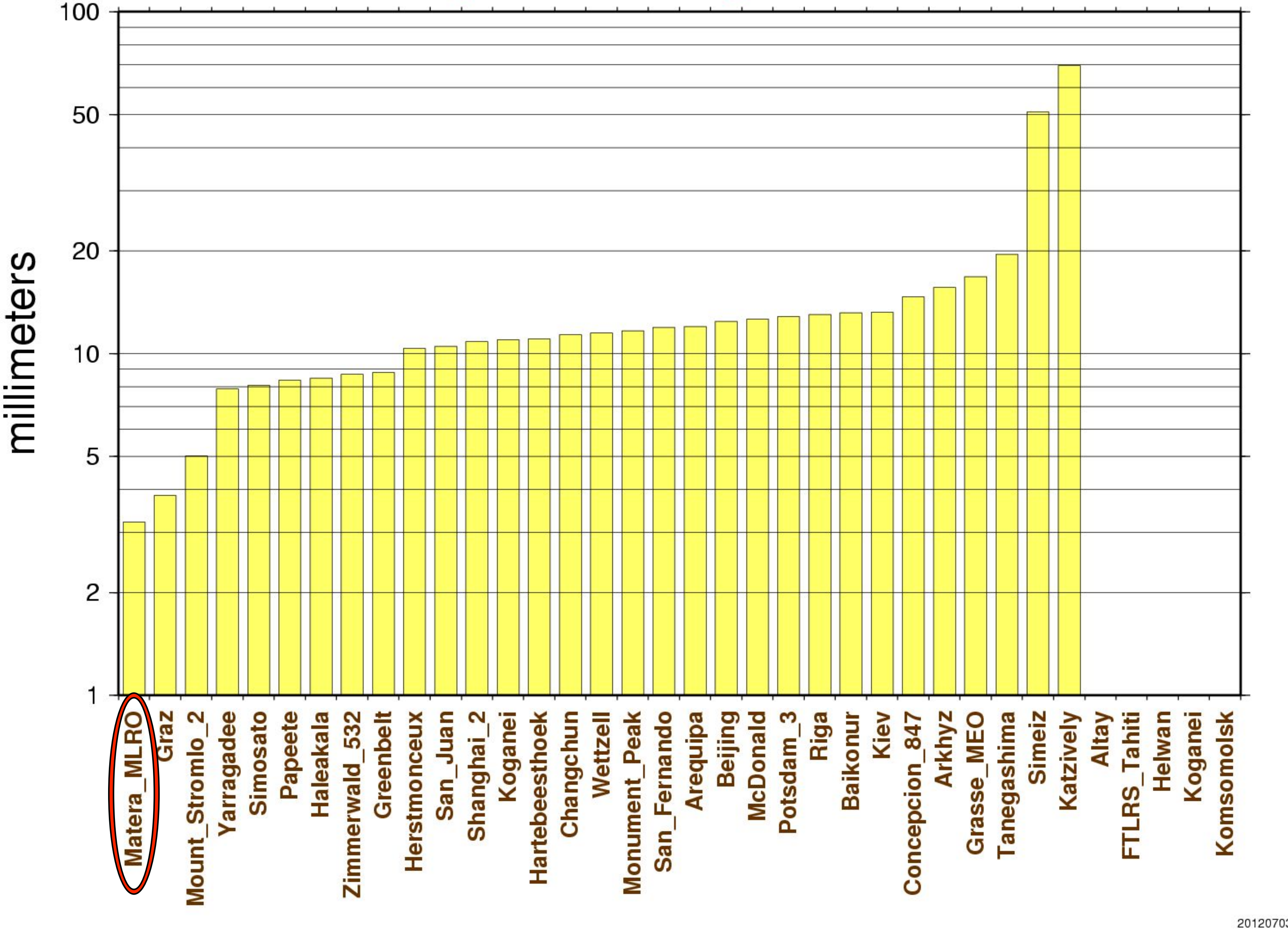

LARES 2012.09.15
Passes
Passes
Station Location
0
100
200
300
400
500
600
Yarragadee
Zimmerwald
Wettzell
Matera
Graz
Greenbelt
Mt Stromlo
Potsdam
Changchun
Herstmonceux
Arequipa
San Juan
Katzively
Haleakala
Monument Peak
Concepcion
Badary
Simeiz
Hartebeesthoek
Baikonur
Beijing
Grasse
Svetloe
San Fernando
Shanghai
Golosiiv
McDonald
Altay
Simosato
Koganei
Zelenchukskya
Tahiti
Tanegashima
Komsomolsk-na-Amure


LARES 2012.09.15
Observations
Observations (NP)
Station Location
10000
8000
6000
4000
2000
0
Yarragadee
Zimmerwald
Graz
Greenbelt
Matera
Wettzell
Potsdam
Herstmonceux
Mt Stromlo
San Juan
Monument Peak
Haleakala
Arequipa
Katzively
Changchun
Badary
Grasse
Hartebeesthoek
Simeiz
Baikonur
Beijing
Svetloe
Simosato
Concepcion
McDonald
Tahiti
Golosiiv
Shanghai
Altay
San Fernando
Zelenchukskya
Koganei
Komsomolsk-na-Amure
Tanegashima

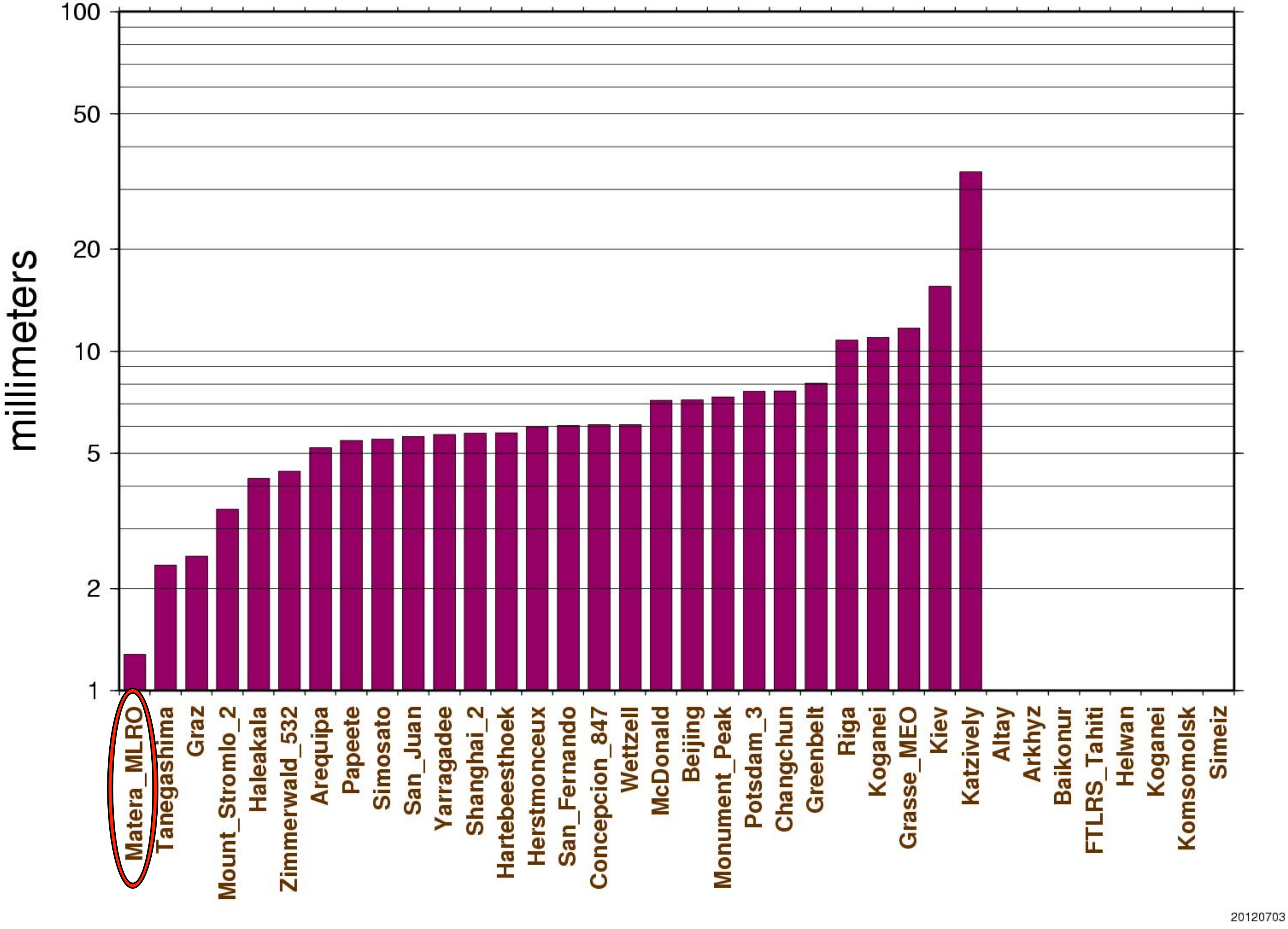
LAGEOS RMS
from April 1, 2012 through June 30, 2012



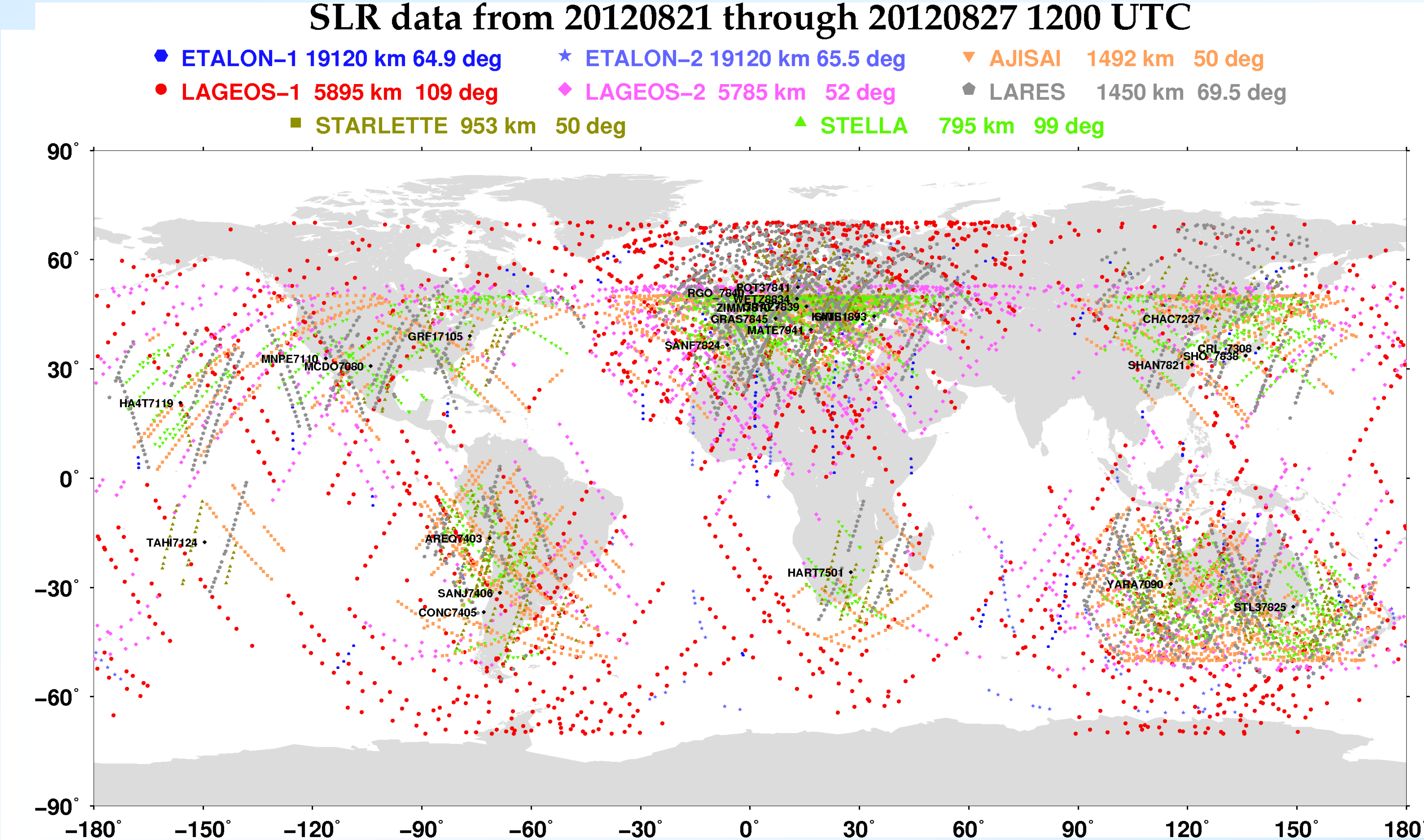
Starlette RMS
from April 1, 2012 through June 30, 2012



calibration RMS
from April 1, 2012 through June 30, 2012



Daily ILRS Tracking for Geodetic Payloads



EUROLAS Data Center (EDC)

Satellite: Lares

Current ILRS Tracking Statistics of Normal Points Data (CSTG)

Station	First Observation	Last Observation	Passes	Observations	Duration
18734901, Simeiz	2012-03-08 00:22:18	2012-03-18 22:31:10	7	52	00:31:19
18931801, Katzively	2012-02-19 03:55:19	2012-03-21 00:18:30	26	216	01:41:31
70802419, McDonald	2012-02-29 10:38:17	2012-03-16 09:11:38	6	34	00:18:55
70900513, Yarragadee	2012-02-17 10:34:57	2012-03-22 05:51:38	127	1858	14:40:10
71050725, Greenbelt	2012-02-17 21:41:47	2012-03-22 04:49:37	48	707	05:42:22
71100412, Monument Peak	2012-02-18 01:36:54	2012-03-15 20:28:44	19	271	02:03:36
71191402, Haleakala	2012-02-24 01:05:17	2012-03-20 22:57:10	17	246	01:57:43
71240802, Tahiti	2012-03-07 10:35:57	2012-03-20 10:32:40	5	74	00:36:30
72371901, Changchun	2012-02-24 19:41:51	2012-03-21 19:29:08	30	240	01:54:28
72496102, Beijing	2012-03-14 16:58:54	2012-03-14 17:03:45	1	11	00:04:52
73085001, Koganei	2012-02-20 05:09:27	2012-03-12 17:19:05	4	43	00:19:01
73588901, Tanegashima	2012-03-21 15:22:55	2012-03-21 15:27:04	1	10	00:04:10
74031306, Arequipa	2012-03-06 05:51:28	2012-03-15 18:50:01	9	84	00:57:29
74057904, Concepcion	2012-03-01 05:13:41	2012-03-21 16:26:31	37	148	03:17:21
74068801, San Juan	2012-02-24 07:41:57	2012-03-22 04:30:05	38	434	03:25:23
75010602, Hartebeesthoek	2012-03-12 22:29:28	2012-03-20 21:59:12	6	105	00:48:47
78106801, Zimmerwald	2012-02-20 16:42:48	2012-03-22 07:11:43	97	1503	13:32:55
78212801, Shanghai	2012-03-13 17:58:45	2012-03-13 18:06:12	1	13	00:07:28
78244502, San Fernando	2012-03-06 04:22:05	2012-03-19 02:13:48	4	10	00:02:56
78259001, Mt Stromlo	2012-02-17 18:54:52	2012-03-20 12:18:46	26	203	01:39:20
78383603, Simosato	2012-02-20 07:06:50	2012-02-27 18:30:43	3	53	00:27:05
78393402, Graz	2012-02-17 13:58:49	2012-03-22 01:12:08	49	895	07:45:53
78403501, Herstmonceux	2012-02-25 15:14:20	2012-03-22 01:06:06	24	268	02:00:22
78418701, Potsdam	2012-02-20 06:40:46	2012-03-22 09:09:06	31	459	03:38:43
78457801, Grasse	2012-02-21 13:34:21	2012-03-21 08:19:14	25	385	03:36:24
79417701, Matera	2012-02-18 04:49:51	2012-03-22 01:05:11	40	459	03:47:32
88341001, Wettzell	2012-02-21 05:33:20	2012-03-22 07:14:18	34	304	02:40:18

Last Update: 2012-03-22 10:00:43

EUROLAS Data Center (EDC)

Current ILRS Tracking Statistics of Normal Points Data (CRD)

Station	First Observation	Last Observation	Passes	Observations	Duration
18248101, Golosiiv	2012-03-23 21:01:25	2012-08-09 21:08:30	45	359	03:07:47
18685901, Komsomolsk-na-Amure	2012-05-09 16:15:51	2012-05-31 12:32:07	5	52	00:27:31
18734901, Simeiz	2012-03-08 00:22:18	2012-09-15 00:08:35	103	1036	10:32:40
18799401, Altay	2012-04-25 15:18:40	2012-09-09 15:35:07	38	358	04:17:22
18879701, Baikonur	2012-05-04 19:31:38	2012-09-12 22:20:47	90	921	10:23:31
18889801, Svetloe	2012-03-07 01:30:45	2012-08-15 22:37:37	67	521	04:11:57
18899901, Zelenchukskya	2012-04-05 20:52:41	2012-05-19 21:15:01	26	312	02:51:39
18900901, Badary	2012-03-03 20:54:34	2012-08-20 13:25:45	126	1450	12:56:37
18931801, Katzively	2012-02-19 03:55:07	2012-09-15 02:03:23	162	1726	13:39:49
70802419, McDonald	2012-02-29 10:38:17	2012-08-30 02:56:48	45	385	04:30:00
70900513, Yarragadee	2012-02-17 10:34:54	2012-09-15 08:49:20	593	8717	02d 23:18:55
71050725, Greenbelt	2012-02-17 21:41:37	2012-09-14 21:45:43	293	4125	01d 10:36:51
71100412, Monument Peak	2012-02-18 01:36:49	2012-09-14 02:35:02	143	2206	17:37:34
71191402, Haleakala	2012-02-24 01:05:06	2012-09-15 03:24:37	155	2166	18:16:21
71240802, Tahiti	2012-03-07 10:35:53	2012-09-05 16:42:03	24	370	03:04:26
72371901, Changchun	2012-02-24 19:41:48	2012-09-14 20:17:54	239	1661	14:02:45
72496102, Beijing	2012-03-14 16:58:54	2012-09-14 18:21:26	87	586	08:49:52
73085001, Koganei	2012-02-20 05:09:27	2012-09-10 18:45:41	26	268	02:07:58
73588901, Tanegashima	2012-03-21 15:22:40	2012-04-17 12:05:52	6	51	00:24:23
74031306, Arequipa	2012-03-06 05:51:25	2012-09-14 09:07:23	203	2005	21:12:02
74057904, Concepcion	2012-03-01 05:13:31	2012-09-12 19:30:48	129	487	13:12:17
74068801, San Juan	2012-02-24 07:41:54	2012-08-28 23:50:32	195	2397	19:55:54
75010602, Hartebeesthoek	2012-03-12 22:29:18	2012-09-14 03:26:52	101	1136	09:27:09
78106801, Zimmerwald	0000-00-00 00:00:00	0000-00-00 00:00:00	514	7446	00:00:00
78212801, Shanghai	2012-03-13 17:58:21	2012-09-01 12:14:38	53	359	02:58:07
78244502, San Fernando	2012-04-22 20:14:12	2012-09-14 03:05:05	61	354	02:48:45
78259001, Mt Stromlo	2012-02-17 18:46:03	2012-09-13 19:56:38	269	2730	02d 00:28:34
78383603, Simosato	2012-02-20 07:06:50	2012-09-10 08:34:07	33	508	04:17:42
78393402, Graz	2012-02-17 13:53:12	2012-09-12 01:24:48	317	5986	04d 03:09:41
78403501, Herstmonceux	2012-02-25 15:13:58	2012-09-14 23:59:43	226	2896	01d 00:02:50
78418701, Potsdam	2012-02-20 06:40:10	2012-09-14 01:07:58	240	3241	01d 06:18:06
78457801, Grasse	2012-02-21 13:34:21	2012-09-15 00:06:35	77	1191	10:39:55
79417701, Matera	2012-02-18 04:49:34	2012-09-12 16:10:36	341	3865	01d 10:04:38
88341001, Wettzell	2012-02-21 05:33:20	2012-09-14 18:01:38	420	3857	14:-8:-26

Last Update: 2012-09-15 20:02:29

LARES 1st ARC (2/17-2/21)

1 RESIDUAL SUMMARY BY STATION AND TYPE FOR ARC 1 INNER ITERATION 2 OF GLOBAL ITERATION 3 UNIT 6

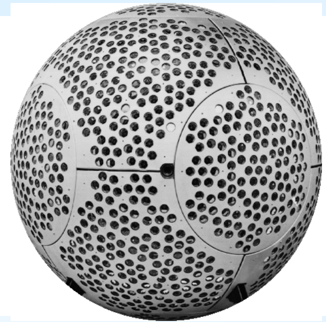
0 NUMBER	MEAN	RMS	NO.-WTD	WTD-MEAN	WTD-RMS	WTD-RND	TYPE	CONFIGURATION
236	0.0000	0.0164	236	0.0000	0.0164	110.5413	2W RANGE	Yarragad 1200601
32	-0.0001	0.0097	32	-0.0001	0.0097	50.8085	2W RANGE	Graz 1200601
16	0.0001	0.0108	16	0.0001	0.0108	18.8162	2W RANGE	Mount St 1200601
65	0.0000	0.0118	65	0.0000	0.0118	271.3089	2W RANGE	Greenbel 1200601
16	-0.0002	0.0151	16	-0.0002	0.0151	62.4799	2W RANGE	Monument 1200601
9	-0.0010	0.0164	9	-0.0002	0.0041		2W RANGE	Katzivel 1200601
24	0.0014	0.0618	24	0.0003	0.0154	76.7157	2W RANGE	Koganei 1200601
60	0.0000	0.0107	60	0.0000	0.0107	13.3553	2W RANGE	Potsdam 1200601
20	0.0018	0.0098	20	0.0004	0.0024	33.0524	2W RANGE	Simosato 1200601
74	0.0000	0.0129	74	0.0000	0.0129	115.6550	2W RANGE	Zimm@532 1200601
31	0.0000	0.0106	31	0.0000	0.0106	15.0981	2W RANGE	Wettzell 1200601

```
1          RESIDUAL SUMMARY BY MEASUREMENT TYPE FOR ARC  1 INNER ITERATION  2 OF GLOBAL ITERATION 3     UNIT  6
0          NUMBER            MEAN             RMS   NO.-WTD          WTD-MEAN          WTD-RMS     TYPE
0      583           0.0001          0.0183     583              0.0000           0.0136   2W RANGE
0             TOTAL  NUMBER  OF  OBSERVATIONS =        583  EDITING  RMS =         0.0187
              NUMBER OF OBSERVATIONS DELETED DUE TO CUTOFF ANGLE =         0
              NUMBER OF WEIGHTED OBSERVATIONS =        583  WEIGHTED RMS =         0.0140
```

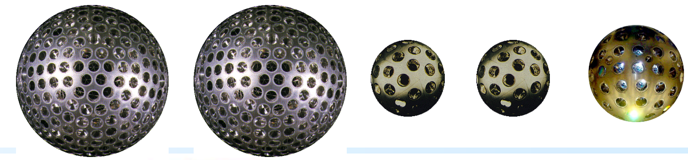
Improvement Expected from LARES

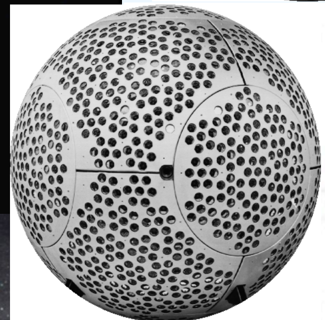
- Simulations of ITRF development with LAGEOS 1 & 2 data were compared to cases where LARES simulated data were included, and the results are remarkable
- As far as the origin of the ITRF, i.e. the definition of Earth's "**geocenter**":
  - We can expect a **25-30%** improvement
- The extremely difficult to determine today "**velocity of the geocenter**" (due to mass transport in the system), will benefit even more
  - The improvement will be about **40%**
- The latter is due to LARES' high inclination and complementary orbit to that of LAGEOS

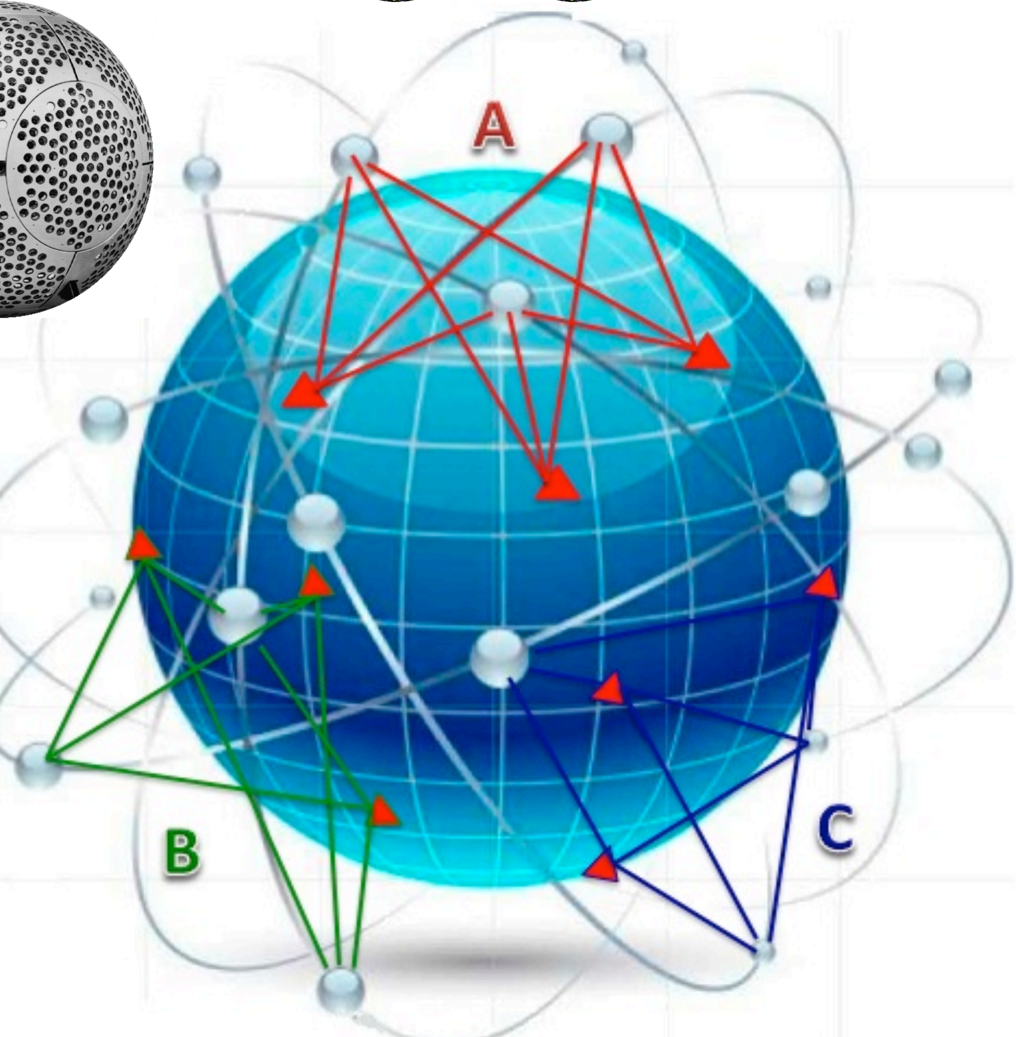
Typical GNSS S/C



SLR Cannonball S/C







ILRS Network

Thank you!