Station Operation Issues

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Abstract: Three historical weaknesses of SLR are weather dependency causing temporal and spatial coverage outages; non-uniform distribution of sites, especially in the southern hemisphere, and network performance diversity. The ILRS has done much to improve upon the later two issues the past several years, but more needs to be done.

In the rest of this paper, we will discuss current station operational issues and recommendations for improvement in the areas of data quantity, data quality, and site compliance.

Introduction:

Station operational issues can be broken into three broad categories (data quantity, data quality, and operational compliance). Each of these categories can be further sub-divided.

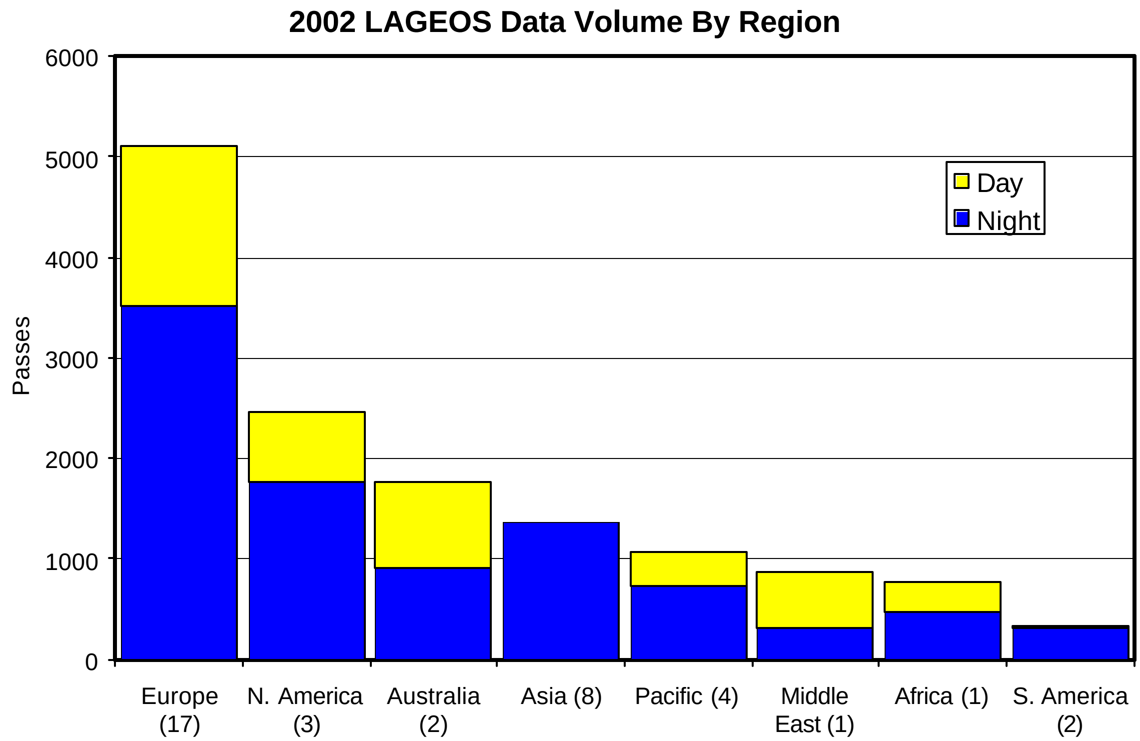
Data Quantity:

First, we will investigate data quantity issues by looking deeper into which factors, besides weather, are limiting data production. The ILRS network track the following 4 classes of satellites based on range:

- Low Earth Orbiting (LEO), <2000Km,
- LAGEOS, 6000Km,
- High, >20,000Km, and
- Moon, >350,000Km.

After weather, a system's inherent capabilities have the next greatest influence on its productivity. Figure 1, below, is the LAGEOS data volume in 2002 by geographic region. The number of contributing sites is listed in '( )' under the region name. Please notice that in 2002, Asia and S. American Sites had virtually no day time LAGEOS data.

Figure 1: LAGEOS 2002 Data Volume (Passes)



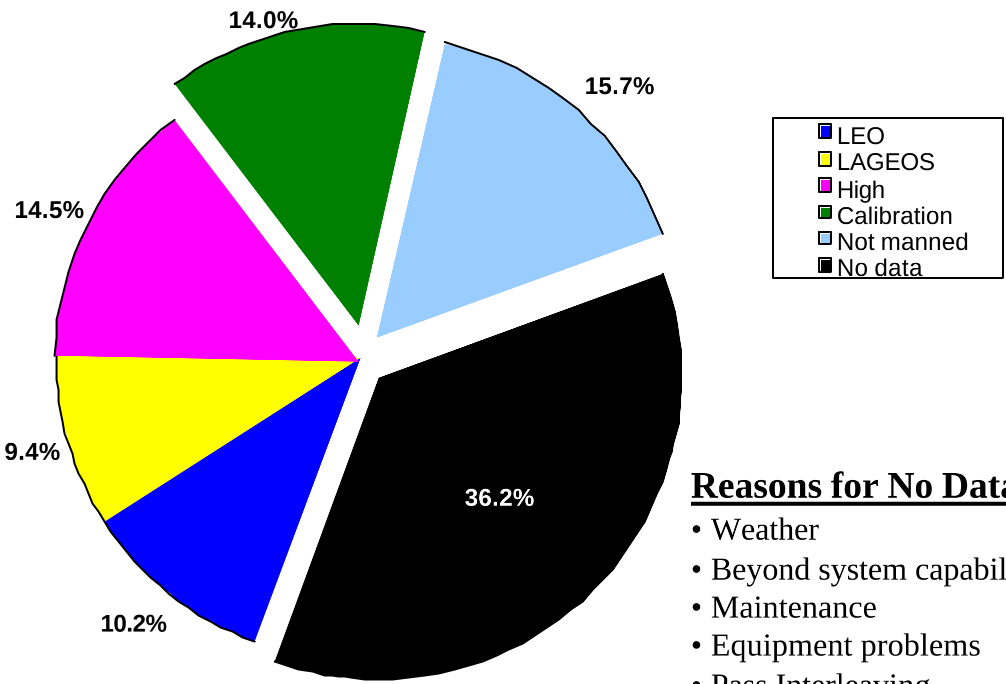
Yarragadee set a single month tracking record of 1165 passes during February 2002, averaging better than 41 passes/day. Let's see if we could learn something from this record performance. Yarragadee tracked 83% of every scheduled pass in this month (see Figure 2). Yarragdee's success rate was satellite dependent, with the BEST percentages being on the LEO satellites, except for Starshine. Starshine is a cannon-ball satellite (i.e. passive) in a very low orbit with limited SLR tracking success, which makes its orbit difficult to predict. Yarragadee's LAGEOS performance level was much lower than its LEO performance, mostly due to difficulty acquiring LAGEOS in daytime.

Despite tracking 83% of all scheduled passes, Yarragadee was tracking satellites only 34.1 % of the total available time in February 2002. See the pie chart in Figure 3 for more information. Approximately, two thirds of the time, Yarragadee was either taking calibration data, was unmanned, or was down for weather, maintenance, equipment problems and/or failed tracking attempts. In-depth analysis of a typical tracking day (see Figure 4) provides further insight into tracking performance limitations in the daytime. Notice there is no high satellite data in the daytime and the drop off in LAGEOS data yield.

Figure 2: Yarragadee February 2002 Operating Efficiency by Satellite

Satellite	Class	Passes	Scheduled	Percent	Comment
Etalon-1	High	15	**16**	**94**	**Satellite mostly available in daytime**
Etalon-2	High	40	45	**89**	
GLONASS-80	High	19	59	**32**	
GLONASS-84	High	47	76	**62**	
GLONASS-86	High	1	3	**33**	
GLONASS-87	High	9	12	**75**	
GPS-35	High	47	49	**96**	
GPS-36	High	41	43	**95**	
LRE	High	3	3	**100**	
LAGEOS	LAGEOS	94	117	**80**	
LAGEOS-2	LAGEOS	70	115	**61**	**Interference with the sun**
Ajisai	LEO	149	154	**97**	
BEC	LEO	43	49	**88**	**Satellite is magnetically stabilized**
Champ	LEO	48	48	**100**	**Used drag function and sub-daily predicts**
ERS-2	LEO	67	71	**94**	
GFO	LEO	70	76	**92**	
Jason	LEO	87	91	**96**	
Reflector	LEO	60	77	**78**	
Starlette	LEO	97	99	**98**	
Starshine	LEO	5	37	**14**	**Very low satellite with no GPS**
Stella	LEO	58	60	**97**	
Topex/Poseidon	LEO	95	96	**99**	
Totals		**1165**	**1396**	**83**	

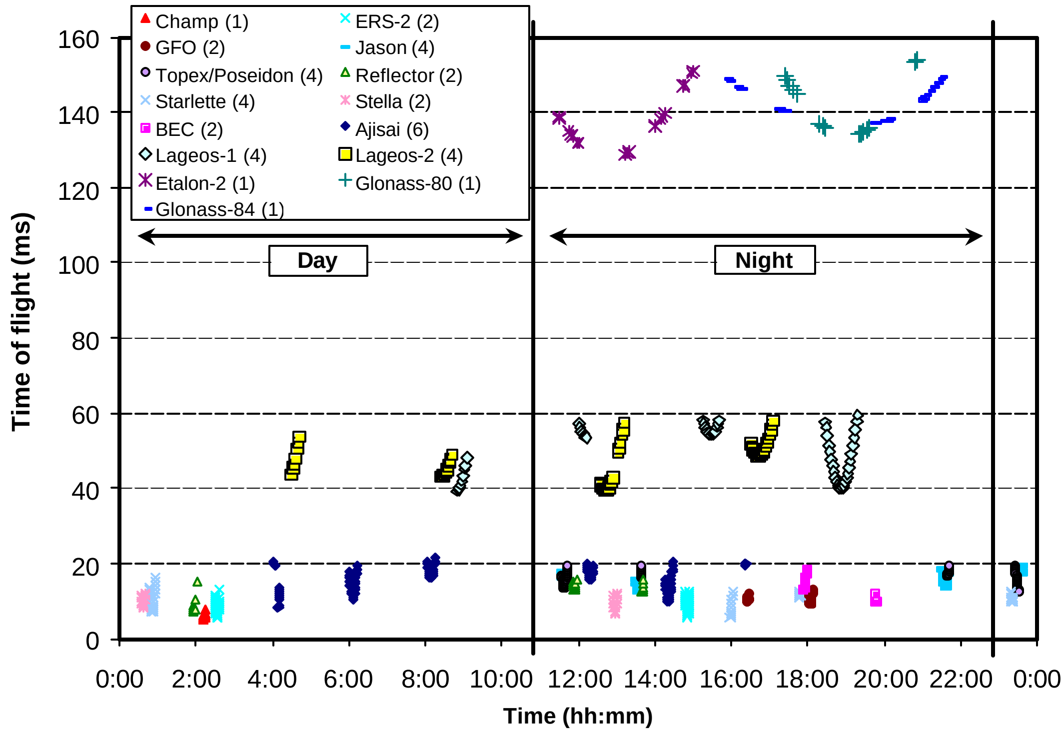
Figure 3: Yarragadee February 2002 Performance Breakdown.



Reasons for No Data

- Weather
- Beyond system capability
- Maintenance
- Equipment problems
- Pass Interleaving

Figure 4: Yarragadee Tracking Results on February 8th 2002.

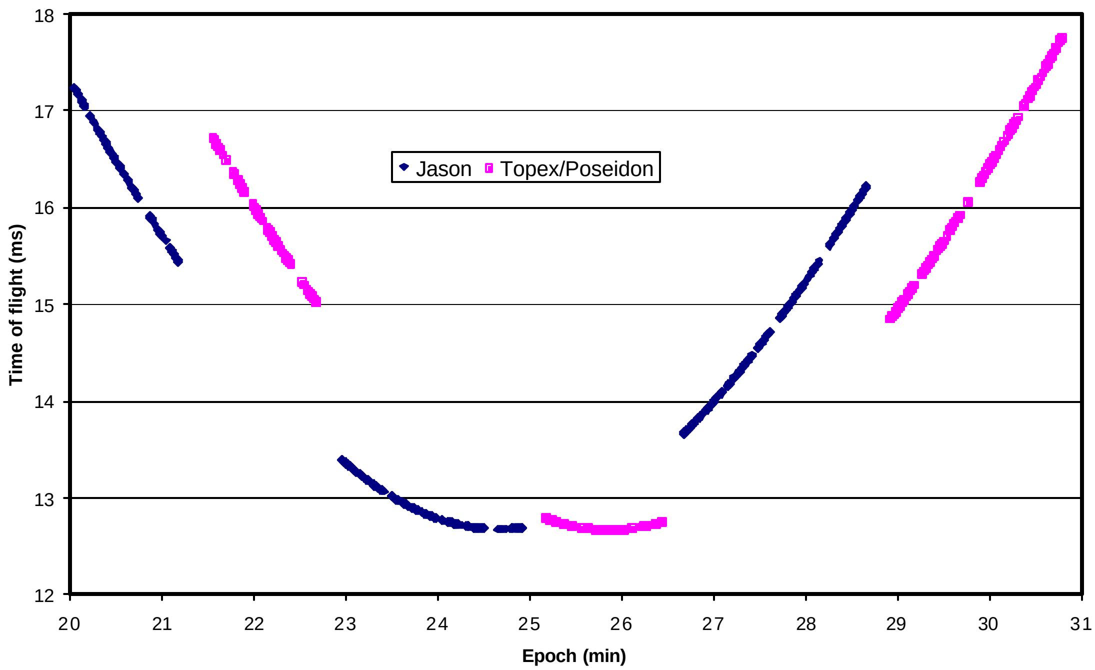


Based on the Yarragadee mission analysis, its appears the greatest potential for improving data yield is to reduce the amount of calibration time, improve daytime ranging capability to LAGEOS and the high satellites, operate the station round the clock (i.e. 24 hours a day, 7 days a week, 365 days a year) or totally automate the system, and track below 20 degrees of elevation. Currently, only two sites (Graz and Grasse) routinely track below 20 degrees of elevation. Tracking below 20 degrees will provide better spatial coverage and the necessary data to test different tropospheric refraction models.

Ranging to satellites in very low earth orbits (<500km) is challenging, because the passes are very short in duration, the mount must keep pace with the satellite, and predictions can quickly degrade. SLR prediction (i.e. Tuned Inter-Range Vector, TIRV) quality can be greatly enhanced on these very low satellites, if the satellites are equipped with GPS receivers and if the GPS data is made available in near real time to the SLR prediction centers (e.g. CHAMP, GRACE-A,-B). But still the predictions tuning process induces a systematic time bias due to drag. Most of this error can be approximated with drag functions, but a small drifting residual error can persist. This remaining time bias can be accurately determined by passing the TIRV through the SLR normal point data. Our colleagues at NERC and Zimmerwald have automated the task of computing TIRV time biases in near real time, which has greatly enhanced the success rate on tracking these very low satellites.

Another item that is data quantity related is pass interleaving. Many stations within our network are capable of switching between satellites within a few seconds, especially satellites in the same orbit (e.g. Jason and TOPEX, GRACE-A and GRACE-B). Figure 5 is an example of Zimmerwald quickly switching between Jason and TOPEX/Poseidon. Mission owners need to be aware of ILRS system capabilities to develop the optimum tracking strategy to maximize their science results.

Figure 5: Zimmerwald Pass Interleaving.



Data Quality:

The highest performing SLR systems have been producing LAGEOS normal points with 1 to 2 millimeters precision since the mid-1980's. Data precision has not been a weakness of SLR, but the same cannot be said for systematic errors. Therefore, the prime operational issue, in regard to SLR data quantity, is to minimize and/or hopefully eliminate all systematics errors to the 1-2 millimeter level in the ranging data. This needs to be done on 3 temporal resolutions (within a pass, from pass-to-pass, and from month-to-month).

Systematic errors fall into two broad categories (blunders and subtle). Blunders exceed 0.1 meters in range bias or 50 microseconds in epoch and can usually be eliminated with better operating procedures. The top 5 most common blunders in SLR data are:

1. Epoch errors
2. Meteorological blunders
3. Single point normal points in the 1st or last bin
4. Mis-calibration of the laser semi-train
5. Use of internal frequency for the time-of-flight device

Common epoch errors include a date error, usually one day, or a frame error. Meteorological blunders are frequently caused by data entry errors. The failure to identify and edit outliers in statistically weak bins, especially near the beginning or end of a pass or after a gap in tracking, can be problematic and cause the formation of erroneous normal points. Systems, which transmit the laser semi-train, process the data by folding the different trains into a single track, but sometimes the wrong baseline track is selected.

Subtle errors in SLR data can exist at the few millimeters or the few centimeter level, which are difficult to detect in orbital analysis. In order to remove and identify these subtle errors, better calibration practices and better system characterization techniques need to be developed, respectively. The top 5 most commonly occurring subtle errors in SLR data are:

1. Un-calibrated meteorological sensors
2. Different receive signal strengths between satellite and calibration
3. Target signature variations due to changes in return photo electron level
4. Un-calibrated counter non-linearities [Gibbs, 2002]
5. Errors in local surveys (e.g. target ranges, system eccentricities)

A barometric error of one millibar induces an elevation dependent range bias of 7 mm and 3 mm at 20 degrees and zenith, respectively. A 10 % humidity error at 20 degrees C. causes a 1 mm range error at 20 degrees of elevation. Sites need to have a secondary barometric sensor in order to perform daily or at least weekly comparisons at the 0.1 millibar level [Kirchsner, 2003]. Both units need to be calibrated annually to a known standard. If an error creeps in the one of the meteorological devices, then a data correction algorithm can be provided.

All detectors (i.e. PMTs, MCP-PMTs, SPADs, and APDs) have dependencies with receive signal strength. These variations can be modeled to some extent in the hardware or in data processing.

The keys to our success will be to improve our bias detection capabilities both on-site and from the analysis centers. The sites must be proactive in removing known systematics in their data. Best calibration practices need to be established, communicated, and followed for the total system and each major sub-system of the ranging machine.

Operational Compliance:

The main operational compliance issues are keeping site logs current, ensuring the site has an operational GPS receiver in close proximity (i.e. less than a few hundred meters of the SLR system), performing periodic and accurate local survey ties, and timely normal point data delivery in the proper format.

Recommendations:

In order to improve operational efficiencies and data quality sites need to:

1. more fully automate their system operations including data entry and data processing;
2. develop better on-site diagnostics capabilities;
3. incorporate state-of-art technology (funds permitting) into their systems;
4. better adherence to known BEST calibration practices; and
5. more aggressively pursue and correct known degradations in their performance.

References:

Gibbs P., 2002, "Inter-comparison of various timing devices against a single SR timer", Proceedings of the 13th International Laser Ranging Workshop, Washington DC, USA.

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