ILRS Standardization of Hardware, Software, and Procedures

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ABSTRACT

Over the years, the ILRS has established and refined standards for station performance. However, standardization of hardware, software, and procedures appropriate for ILRS stations and operations, analysis, and data centers has been spotty. Advantages and disadvantages of standardization are explored. Finally, a proposal is made to augment the current performance-based standards with a standard station reference design and additional software as a way to facilitate new station construction.

1 Introduction

Whenever a technology advances beyond it primitive stage, there is an urge to establish standards to pass the collective wisdom on to other potential users and to keep acceptable options at a manageable level. The technology used in the International Laser Ranging Service is no exception. The organization has standards for many activities from data distribution procedures to data formats. The overarching standard for the entire group is the stations' level of performance. The issue of standards is examined here in terms of the level of standardization that best promotes the goals of the ILRS. In discussing this topic, one must consider what is already standardized, what can be standardized, and how standards can be enforced. As an outcome of these discussions a proposal is presented to codify the ILRS best practices into a laser ranging station reference design.

2 Standardizing on Performance

The ILRS currently focuses on levels of performance of each of its stations, publishing a quarters "report card" for all the world to see. [1] The guidelines that separate the high performance stations from those aspiring to perform well were presented at the Shanghai laser workshop in 1996 and published on the ILRS web site [1]. They are as follows.

Yearly Data Quantity Guidelines

- 1000 Low Earth Satellite (LEO) passes
- 400 LAGEOS 1,2 passes
- 100 High Satellites passes

Data Quality Guidelines

- 1 cm LAGEOS normal point precision
- 2 cm short term bias stability
- 1 cm long term bias stability

Operational Compliance Guidelines

- Data delivery with 12 hours (latency)
- Specified ILRS normal point format
- Current site and system information form (i.e., site log)

In addition to the performance standards, the ILRS web site provides many standards for data formats, sample software, and various procedures.

3 What do we want from standardization?

There must be a point to having standards. For instance, they need to encourage reliable, accurate performance, which is especially true as the stations push their accuracy to the 1 mm level. To reach this and related goals, the standards must incorporate the best mature hardware, software, and procedures available. Some of the results should be a reduction in cost of design, operations, and maintenance of laser stations and their sub-systems. While there will always be a need for research on new or refined techniques, good standards will reduce unproductive duplication of effort. However, standards should not stifle creativity and progress, but channel it, and encourage innovation and flexibility. Standardization should be a resource, not a "ball and chain."

4 Who and what is involved?

It is important to identify the stakeholders in the standardization discussion. The stations will receive most of the attention, since they are the critical point where data is taken and processed. Stations are complicated systems, encompassing hardware, software, and procedures which must be considered for standardization. Standards for the operations, data, and analysis centers deal mainly with procedures, as will be explained below. Also below, the current status and potential expansion of standardization is examined for hardware, procedures, and software/algorithms by stakeholder.

4.1 Hardware (Stations)

Listed below are some of the hardware subsystems found on nearly all laser ranging stations. These are all candidates for some type of standardization.

Time standards (GPS, cesium, etc.)	Laser (10Hz, 100Hz, 2kHz, 10kHz)
Range gate generator	Timers (event and interval; some to avoid)
Detectors (APD, SPAD, MCP)	Calibration piers
Radar	Telescope/dome
Other infrastructure	

Delving into standards for each of these items is beyond the scope of this paper. However, it should be mentioned that one difficulty in creating a set of stations with identical hardware is that the market changes quite rapidly. Today’s best detector may not be on the market in 6 months or may have been produced in limited quantities, and 2 copies of the same timer model may not contain the same components. While the ILRS workshop papers show a certain undercurrent of commonality in many of these subsystems, the bottom line is that each station is its own standard.

4.2 Procedures

4.2.1 Stations

Some of the key areas of the ranging stations with important procedures are listed below. Many of these overlap with underlying hardware and software that implement them.

Surveys (how often; what gets surveyed)	Range calibrations (how often, etc.)
Prediction and restriction (Go/No-go) downloads	Ranging satellites
Status messages (NASA LORs; EUROLAS status)	Ranging data uploads
Site log/system configuration file maintenance	Adding new targets
Station change notice (for data quarantine)	Telescope mount modeling

Where these procedures interface with the rest of the network, such as prediction download and data uploads, standardization already exists to prevent chaos. Creating the required procedures is only the first step. The stations must then actually use the procedures to conduct surveys, maintain site log and configuration files, and send station change notices to the ILRS!

4.2.2 Centers

Operations centers need to ingest and distribute new data at a certain time and from/to specific locations. They also need to screen the data for format compliance and perform quality checks. They also must handle quarantined data from new and updated stations and make it available only to analysts for validation. Data centers also need to ingest and distribute new data at a certain time and from/to a specific location. They also report data statistics.

Analysis centers have the same need to ingest data, along with screening and fitting data to solve for a host of parameters. They also create and distribute data products for the ILRS. Another part of their effort is to validate new or upgraded stations to insure that data quality is acceptable. They also tell stations when they find problems with data.

Many of the procedures above are already standardized to allow for consistent handling of ranging data and products. Some procedures such as handling quarantined data are works in progress. Quarantining data also requires the stations to make it known when significant changes have been made to their equipment. There are differences in the content and philosophy of creating daily normal point files, and the data screening done by the EDC and NASA OCs is somewhat different. The file and directory naming conventions are generally compatible between the centers for data in the CRD format, for which consistency has been a priority. The naming disparities with the old data format are considerably more serious.

4.3 Software/Algorithms

While it is quite important to have fully documented algorithms, having the algorithms implemented in ready-to-use source code can make life much easier for station developers and maintainers. Each station has a common set of software needs, often expressed and implemented in very different ways. It is important to examine which of these needs can be filled with a standard piece of software. As an alternative to standard code, sample code has been made available for certain projects like Consolidated Prediction Format (CPF) and Consolidated Ranging Data format (CRD). The distinction is that sample code consists of programs or subroutines that can be tailored to the needs of each station, or can just be a starting point for writing custom code. Standard code would be used as written.

4.3.1 Station Data Acquisition

There are several areas in which the data acquisition system, to the extent that is a separate from the data reduction system, presents several opportunities for standardized, or at least sample, code. Some of these are discussed below.

Telescope mount model fitting: Software that takes stars' observed-calculated (o-c) point angle residuals and fits them to a particular mount model is something each station needs. The mount model itself may be different at each station due to mount peculiarities. However there is a common set of 5-10 terms most telescopes will need, so including at least a basic model would be helpful. Other mount-specific terms can be added by the stations as needed. The software to point and track the stars to take the o-c residuals will contain more station dependencies, although the NASA network is able to run 5 different telescope designs with one carefully "ifdef-ed" program. There is also a need for other mount model software to handle very telescope-dependent needs, such as Fourier transform modeling of optical encoders.

Star and planet prediction and refraction: There are at least 2 sets of well-tested free star and planet prediction software packages available to developers, the US Naval Observatory's NOVAS code and the Rutherford-Appleton Labs Starlink (now maintained by the University of Hawaii). [2][3] JPL provides FORTRAN and c code to manipulate its DE series of lunar and planetary ephemerides. [4] There are also several refraction routines available, one developed by Mendes and Pavlis, who are involved in ILRS analysis. [5]

Sun avoidance: Whenever laser stations are engaged in daytime ranging, it is very important to keep the telescope from pointing at the sun. Many stations have developed algorithms and code to accomplish sun avoidance, so it is also a good candidate for standardization.

Tracking restrictions: In the last few years, it has become increasingly important for stations to implement methods of getting and using go/no-go files, pass segment files, and the like. [6] While much of the code for this task remains station-dependent, the ILRS could gain from having publicly available code capable of interacting with the standard restriction file formats.

Prediction sample routines: FORTRAN and c routines to read, write, check, interpolate, and convert CPF files already exist on the ILRS website. [7]

Range data sample routines: Similar to the CPF code, FORTRAN and c routines to read, write, check, and convert CRD format files are also available. [8]

There are undoubtedly more data acquisition system software packages that could become candidates for standardization, depending on the level of hardware abstraction used. At some point in the SLR data acquisition system, ranging and computer system hardware and operating system dependencies make further standardization difficult if not impossible..

4.3.2 Station Data Processing

There are some clear candidates for standardization on the station data analysis system. Prediction download/preparation and data upload software can be shared among stations with similar operating systems. The data pre-filtering software (e.g., Poisson filtering) and normal point generation are modular enough to be common between systems, although there are one yet available from the ILRS. In fact, there is already a set of routines called *distrib* on the ILRS web site that calculates data averages, moments, and the like, and can be used as the heart of data calibration programs. [9] Of course, the CPF and CRD sample code mentioned above also has application on the data processing systems. Some years ago, Herstmonceaux made available the *npcheck* program. It checks normal points for obvious errors including out-of-bound rms-es and calibration values. Another example is the *eurostat* software, developed at Zimmerwald, which has made sharing current station status simple. [10] There is a clear need for additional "standard" programs to be made generally available to ILRS stations.

4.3.3 Centers

The Operations, Data, and Analysis Centers have less code that has historically been shared. Clearly, it is important than algorithms be similar. CRD/CPF sample code can be used in each of these types of centers. The IERS Conventions (2003 is currently used) offer algorithms and code that the ILRS analysts all use. [11] However, the precision orbit determination (POD) software is decidedly not standardized, with the following programs being used at the operations and analysis centers shown in parentheses. [12]

GEODYN (JCET, ASI, GA)	EPOS (GFZ)	DOGS (DGFI)
GINS (GRGS)	SATAN (NSGF)	NAPEOS (ESA)
Bernese (BKG)		

This is perhaps the area most suited for separate software packages, since using diverse software sets that produce similar results with the same data strengthens ones convictions that the results can be believed. Similar to the overall ILRS standardization philosophy, here the performance is the standard.

5 Standards Enforcement

Standards have no effect unless used. Since the ILRS is a volunteer organization in which each station is funded and operated by different entities, each with its own goals, the ILRS must appeal to common needs to achieve its common goals. Since ILRS members have united to gain benefits from cooperating, educating each ILRS component about the needs and benefits of maintaining standards is the only effective enforcement mechanism. Part of this mechanism has been the agreement that the quarterly report cards with its cut lines can be used to commend good performance or encourage better performance. Those below the line need to improve their hardware, software, and procedures (or funding!) to bring performance up to par and to ensure that their data can be used in a meaningful way.

6 SLR Reference Design

Another approach for using standardization to convey best practices is to maintain an SLR station reference design, probably on the ILRS website. This design would incorporate the best, proven, and available hardware and software, and "best practices" procedures. It would also provide viable alternative standards and their compatibility with other sub-systems. This "station" need not be built, but its design can be a starting point for any group wanting to build or update an SLR station.

The components of such a design would be at least block diagrams of hardware, software, and procedures, a list of manufacturers, a list of deprecated components, reference articles by subsystem, and a list of "experts" for each component or sub-system. Some of these items already exist on the ILRS website, and such a project could unify and fill in the gaps in the existing work. [13]

7 Conclusion

For many reasons, absolute standardization of ILRS satellite laser ranging stations is not possible, even were every station to be replaced. The current standardization on performance, not on hardware and software, has functioned well, but can be augmented by a further online resources, including more "standard" and "sample" software and a station reference design. Standards need to be enforced, but here again, the existing system of quarterly report card provides a good motivator, while education and additional resources provide a good reward for the ILRS's efforts.

Acknowledgments

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