Section 4:

ILRS Operations

Section 4: ILRS Operations

Author: *Carey Noll, Michael Pearlman*
Responsible Agency: ILRS Central Bureau

Overview

The International Laser Ranging Service (ILRS) organizes and coordinates Satellite Laser Ranging (SLR) and Lunar Laser Ranging (LLR) to support programs in geodetic, geophysical, and lunar research activities and provides the International Earth Rotation and Reference Systems Service (IERS) with products important to the maintenance of an accurate International Terrestrial Reference Frame (ITRF). This reference frame provides the stability through which systematic measurements of the Earth can be made over thousands of kilometers, decades of time, and evolution of measurement technology. The Service provides precision ephemerides to support active Earth sensing missions and now foresees support for extraterrestrial missions with optical transponders. The ILRS is one of the technique services of the International Association of Geodesy (IAG).

ILRS Central Bureau

The ILRS Central Bureau (CB) is responsible for the coordination and management of ILRS activities and for the communication with service components and the outside community. The CB establishes operating standards for its components and promotes compliance with these standards. The CB monitors network operations, coordinates satellite tracking, maintains the list of satellites tracked and their priorities, maintains the ILRS website and associated documentation, generates reports on data production and station data quality, and organizes workshops (both the bi-annual International Workshop on Laser Ranging and ILRS Technical/Specialty Workshops). The ILRS CB is managed by NASA Goddard Space Flight Center and meets typically every month to address current issues and monitor operations throughout the service.

The ILRS Central Bureau works with current missions to resolve any issues with SLR tracking support, both from the mission and ILRS standpoint. The CB also coordinates future mission support, accepting new Mission Support Request forms, coordinating approval of these forms through the Missions Standing Committee (MSC) and the Governing Board, and working with the mission to start ILRS tracking support.

Recent Developments

Mission Support

During 2016-2019, the ILRS CB assisted agencies to start new tracking support for 11 missions and three future missions. The CB also coordinated three intensive tracking campaigns. More information about the new mission support and tracking campaigns during the 2016-2019 time period can be found in Section 6 of this report.

Workshop Organization

The ILRS sponsors International Workshops on Laser Ranging (IWLRs) which are typically held every two years. In addition, the ILRS organizes focused technical or specialized workshops in years between the International Workshops on Laser Ranging. In September 2019, the ILRS Central Bureau published new guidelines interested parties should follow when proposing to host future workshops and for the ILRS infrastructure to use in planning these workshops. The guidelines have been published on the ILRS website at: *https://ilrs.gsfc.nasa.gov/about/reports/workshop/ILRS_Workshop_Guidelines.html*.

During 2016-2019, the ILRS Central Bureau assisted the Scientific and Local Organizing Committees for four workshops as shown in Table 4-1 below.

Table 4-1. List of ILRS Workshops, 2016-2019

Workshop and Theme	Dates and Location
20th International Workshop on Laser Ranging "The Path Toward the Next Generation Laser Ranging Network"	October 09-14, 2016 Potsdam, Germany
2017 ILRS Technical Workshop "Improving ILRS Performance to Meet Future GGOS Requirements"	October 02-06, 2017 Riga, Latvia
21st International Workshop on Laser Ranging "Laser Ranging for Sustainable Millimeter Geoscience"	November 05-09, 2018 Canberra, Australia
2019 ILRS Technical Workshop "Laser ranging: To improve economy, performance, and adoption for new applications"	October 21-25, 2019 Stuttgart, Germany

Summaries of these workshops can be found in Section 10 "ILRS Meeting Summaries" of this report.

Updates to Site Log Format and Processing

The ILRS site logs contain critical information for users about the configuration of SLR stations. The Data Formats and Procedures Standing Committee (DFPSC), the Networks and Engineering Standing Committee (NESC), and the ILRS CB developed an updated site log format to clarify and extend the content of several sections in the logs. In addition to the format updates, EDC staff developed web-based procedures for update and submitting site logs through their website. This new system provides an immediate format check for station managers when updating their site logs online. Valid site logs are then automatically submitted to the ILRS CB for final review and approval; once complete, the logs are made available at the CDDIS and EDC and integrated into the ILRS website.

Members of the ILRS CB assisted EDC staff in converting site logs to the new format and reviewing their final updates. Personnel worked with the stations to resolve questions and outstanding issues from the conversion. The new site log format and submission/processing procedures were finalized in 2019 and all current stations utilize the updated format to maintain their information.

Station Performance Assessment Reporting

In 2015, the ILRS updated the station performance standard to require stations to obtain a total of 3500 passes per year in order better realize the goals set by the ILRS and GGOS. ILRS Central Bureau personnel and CDDIS staff developed a new reporting system that generates monthly station performance assessment maps to help ILRS and individual stations improve our understanding of overall network performance and determine steps for improvement. The reports consist of a set of maps for each station that illustrate how the station adheres to the established ILRS system performance standards as well as summarizing tracking capabilities, interleaving, normal points per pass, and priority list compliance. The station-specific maps reflect data assessed over the previous twelve months in various categories:

- General (overall score, total passes, total normal points)
- Adherence to ILRS priority list
- Satellite support by category (e.g., number of passes, number of NPTs/pass, percentage of ILRS standard)
  - Altimetry
  - Geodetic
  - GNSS

The reports, and additional information about the assessment software, are accessible at URL: *https://ilrs.gsfc.nasa.gov/network/system_performance/monthly_station_performance_maps/index.html*.

ILRS Operations and Data Centers

Two ILRS Data Centers (DCs) support the user community by providing an archive of and access to laser ranging data, products, satellite predictions, and related information:

- Crustal Dynamics Data Information System (CDDIS), located at NASA Goddard Space Flight Center (GSFC), Greenbelt MD USA, *https://cddis.nasa.gov*
- EUROLAS Data Center (EDC), located at Deutsches Geodätisches Forschungsinstitut, Technische Universität München, Munich Germany, *http://edc.dgfi.tum.de/en/*

The EDC also serves as an ILRS operations center for receipt and quality control of laser ranging data from a subset of stations in the ILRS network; a NASA operations center provides this service primarily for stations in NASA's SLR network. These OCs exchange validated data on an hourly and a daily basis and then forward these data to the ILRS data centers for user access.

Laser Ranging Data

Laser ranging data consist of the round-trip time measurement (and epoch of measurement) from the ground station to retroreflectors on the satellite or on the surface of the Moon. These data will later be corrected for refraction delay and offset to the satellite center of mass in the case of satellites. ILRS stations routinely transmit two types of laser ranging data: full-rate data, which include all range observations obtained during a satellite's pass, and normal point data, where range observations are averaged over the pass, thus condensing the number of range observations reported for the pass. Users can utilize full-rate data for scientific applications as well as for engineering evaluation of the laser tracking systems and satellite targets. SLR normal points, however, are considered the principle ILRS data set. Stations create normal points by using algorithms to sample and aggregate the full-rate data over time. The altitude of the satellite primarily determines the length of this sampling interval, e.g., lower orbiting satellites use a shorter normal point interval than satellites in a higher orbit.

The CDDIS and EDC data centers provide SLR data files in three forms: hourly, daily, and monthly. Hourly and daily files contain all passes from all satellites received by the operations centers in the previous one-hour/24-hour time span respectively. The third type of normal point data file is a monthly, satellite-specific file that contains data for the particular month. Users then have alternate ways for accessing SLR data, all data received during an hour or day-time span, or all data with timestamps for a particular month.

Satellite Predictions

Stations in the ILRS network require predicted satellite ephemerides to track missions on the ILRS priority list. All satellites approved for tracking by the ILRS must have valid satellite predictions available at the ILRS data centers for access by the stations. For tracking satellites with no restrictions, stations obtain orbit predictions through e-mail or by downloading files from the ILRS data centers. Satellites missions with restricted tracking requirements must provide predictions directly to the stations, thus ensuring that only authorized stations will range to their satellites.

ILRS Products

All ranging data are available at the ILRS Data Centers for the Analysis Centers (ACs) to download for product development. More details on the ILRS products can be found in Section 7.

The ILRS ACs submit their ILRS product solutions to the ILRS data centers on defined schedules; the two ILRS Combination Centers retrieve and combine the AC solutions to generate the official ILRS products, which are then submitted to the DCs for archive and distribution.

Recent Developments

Data Quality Assessment and Review

The ILRS formed the Quality Control Board (QCB) that meets periodically via teleconference to examine data quality issues and to develop new procedures to highlight data quality problems. Tools and procedures have been implemented to better identify systems biases and provide rapid feedback to the stations. There has also been some strengthening in systems engineering to help identify bias sources.

Updates to Data Screening

The ILRS Operations Centers (OCs) at EDC and NASA are in direct contact with the ILRS stations; they collect and merge SLR data and transmit these data to the ILRS Data Centers (DCs) at EDC and CDDIS. In addition, the OCs perform quality control on all incoming data to ensure valid data are forwarded to the DCs for the user community. However, these tests were not extensive, and the checks performed at the two OCs were not identical. In the last few years, the OCs, with input from the NESC and the ILRS CB, developed a series of checks to harmonize their procedures; these checks identified the allowable values or range of values for every field in the CRD format. In August 2019, the OCs implemented an updated data screening process in order to coordinate data quality control (QC) and provide feedback on data issues to the stations. More importantly, both ILRS Operations Centers now utilize the same criteria for screening incoming data. Incoming data with fatal issues are screened out early in the process, and immediate warnings are sent to the stations. Data with minor issues (little of no impact on the data products) are passed on for processing and posting. Diagnostics are forwarded to the stations on a routine basis for necessary action. A summary of the new procedure is available on the ILRS website at: *https://ilrs.gsfc.nasa.gov/network/site_procedures/data_screening_procedure.html*.

ILRS Mirror Data Center

The GNSS Science Support Center (GSSC) at ESA's European Space Astronomy Center (ESAC) submitted an application to the ILRS in November 2018 to become an ILRS Data Center. The ILRS Governing Board accepted their application and designated ESAC/GSSC as an ILRS "Mirror Data Center". Although the role of the current ILRS Data Centers at CDDIS and EDC is much broader, where they are integrated into SLR operations and data flow, a Mirror Data Center at GSSC, once operational, will give the user community another access point for ILRS data, derived products, and service operational and status information. They may also provide other useful services to users.

Outreach Activities

The ILRS Central Bureau maintains the ILRS website on servers managed by CDDIS staff. The website is revised in a timely fashion to include recent news, meeting notices, mission updates, and other service developments.

In November 2019, the Journal of Geodesy published the "Special Issue: Satellite Laser Ranging", This issue, Volume 93, Issue 11, November 2019, editors Erricos Pavlis, Vincenza Luceri, Toshimichi Otsubo, Ulrich Schreiber, consists of twenty papers detailing recent developments in SLR. A list of papers published in the special issue is available at *https://link.springer.com/journal/190/93/11/page/1*.

Efforts are being made to bring IAG Services closer together; a joint meeting between the ILRS and the IGS was planned to take place at the 2020 IGS Workshop in August 2020, but has been delayed due to the global coronavirus pandemic.

Future ILRS Operational Activities

Updates to ILRS Data and Prediction File Formats

The ILRS Data Formats and Procedures Standing Committee (DFPSC) developed updates to both the prediction (CPF) and data (CRD) formats to accommodate advances in laser ranging since the original introduction of these formats in 2012. These modifications include changes required for time transfer activities, space debris tracking, and other potential applications. Further modifications allow for inclusion of additional information for enhanced diagnostics and correction of other issues that have been identified since the original implementation of the format. The ILRS infrastructure (stations, OCs, DCs, and ACs) are currently testing the new formats.

Updated Global Report Card Software

The ILRS Central Bureau has been generating global report cards on a quarterly basis since 1997 and a monthly basis since 2012. Some assumptions made, which were integrated into the initial software package that created reports prior to 2020, are no longer valid due to operational and technical improvements in the network, such as an increase in the number of targets, different ways in which stations track, and pass interleaving. A new version of the report card software is under development with the help of CDDIS staff. This new software incorporates changes to provide more accurate pass and normal point counts, satellite RMS, and LAGEOS bias information. In addition, the table summarizing LLR data will provide individual lunar retroreflector information. After review by the ILRS Central Bureau, the new software will be used operationally for all report cards generated after January 2020. The ILRS website will provide documentation about the new reports and differences with the previous versions. Furthermore, the new software will be used to generate the data for the previous years' reports (from May 2013 to December 2019), allowing users to compare data from pass years.