SECTION 5
OPERATIONS

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OPERATIONS

Carey Noll/NASA GSFC, Michael Pearlman, CfA, Randy Ricklefs/CSR

ILRS CENTRAL BUREAU COORDINATION

The ILRS Central Bureau was responsible for the daily coordination and management of the ILRS activities including communication and information transfer, monitoring and promoting compliance with ILRS network standards, monitoring network operations and quality assurance, maintaining documentation and data bases, and organizing meetings and workshops. The Central Bureau worked with new missions in preparation for launch, orbital acquisition and assessment of tracking performance, organized the meetings of the Governing Board and issued the meeting notes, documented and assigned action items and monitored progress toward their completions, and met monthly at GSFC and issued meeting notes.

Aside from daily operations and routine monitoring of network and data performance, the Central Bureau also oversaw or participated in the following activities:

- Implementation of the CRD data format for improved range precision and extended range;
- Implementation of restricted tracking procedures for tracking optically vulnerable satellites;
- Update of the ILRS website to include additional charts on network performance, new procedures, and updated forms for new missions and retroreflector specification information;
- Harmonization for data procedures between CDDIS and EDC including a quarantine and verification procedure for new stations or stations returning to operation after major repairs of upgrades;
- Update of the prediction process for improvement in the tracking of satellites in very low orbits;
- Provision of letters of support for stations as required;
- Improved normal point definition for high repetition rate systems to improve data yield;
- Implementation of the new Retroreflector Standard for GNSS satellites for improved GNSS data yield and day light operations;
- Program organization of the 17th International Laser Ranging Workshop in Bad Koetzting to be held in 2011.

The Central Bureau staff also participated in all of the Working Groups and Task Forces.

DATA CENTER DEVELOPMENTS

The ILRS introduced the Consolidated Ranging Data (CRD) format during 2008. CRD provides a flexible, extensible format for ILRS full-rate, sampled engineering, and normal point data. The new format will accommodate new missions, e.g., transponder experiments, and station capabilities such as high-repetition rate lasers. The data centers began support of CRD tests by creating directories and updating data flow procedures. The complete transfer to the CRD format is scheduled for mid 2011.

The ILRS continues to improve data throughput. Data from the field stations are now submitted hourly and made available immediately through the data centers for rapid access by the user community and prediction providers. With this faster submission of data, better quality predictions are available more frequently and prediction quality assessment is available in near real-time.

The ILRS Data Center at the Crustal Dynamics Data Information System (CDDIS)

Introduction

Since 1982, the Crustal Dynamics Data Information System (CDDIS) has supported the archive and distribution of geodetic data products acquired by NASA as well as national and international programs. These data include GNSS (Global Navigation Satellite System), SLR and LLR (Satellite and Lunar Laser Ranging), VLBI (Very Long Baseline Interferometry) and DORIS (Doppler Orbitography and Radiolocation Integrated by Satellite). The CDDIS data system and its archive supports several of the operational services within the International Association of Geodesy (IAG) and its project the Global Geodetic Observing System (GGOS), including the ILRS, the International GNSS Service (IGS), the International VLBI Service for Geodesy and Astrometry (IVS), the International DORIS Service (IDS), and the International Earth Rotation Service (IERS).

CDDIS Operations

The update process for the CDDIS archive process can be divided into several structural components allowing for efficient and secure processing: deposit, operations, download, and archive support.

Deposit: Suppliers of content for the archive (e.g., network tracking data from operational centers, products from analysis centers, etc.) transfer their data and product files to the CDDIS deposit or "incoming" disk location using ftp. These incoming accounts have limited privileges allowing users to only deposit files. In a few cases, the CDDIS will retrieve files for the archive from data/product sources. All suppliers access a server dedicated to receipt of incoming files.

Operations: All processing of incoming files takes place in the CDDIS operations area, which is accessible to internal users only. Software scans the deposit directories on pre-determined schedules dependent upon the type of incoming files and copies the files to temporary locations where their contents are validated for readability and integrity (format and content) and metadata are extracted and loaded into a relational database. Valid files are moved to the CDDIS archive.

Download: The CDDIS public archive is openly accessible to the scientific community through anonymous ftp and the web (future enhancements will permit http access to the CDDIS archive). It is the repository for all valid files provided by the operational/regional/global data centers, analysis centers, and analysis center coordinators. The structure of the archive follows conventions established within the services and thus is data type (i.e., GNSS, SLR, VLBI, or DORIS) dependent. All users access a separate computer system dedicated to serving files from the archive's disk farm.

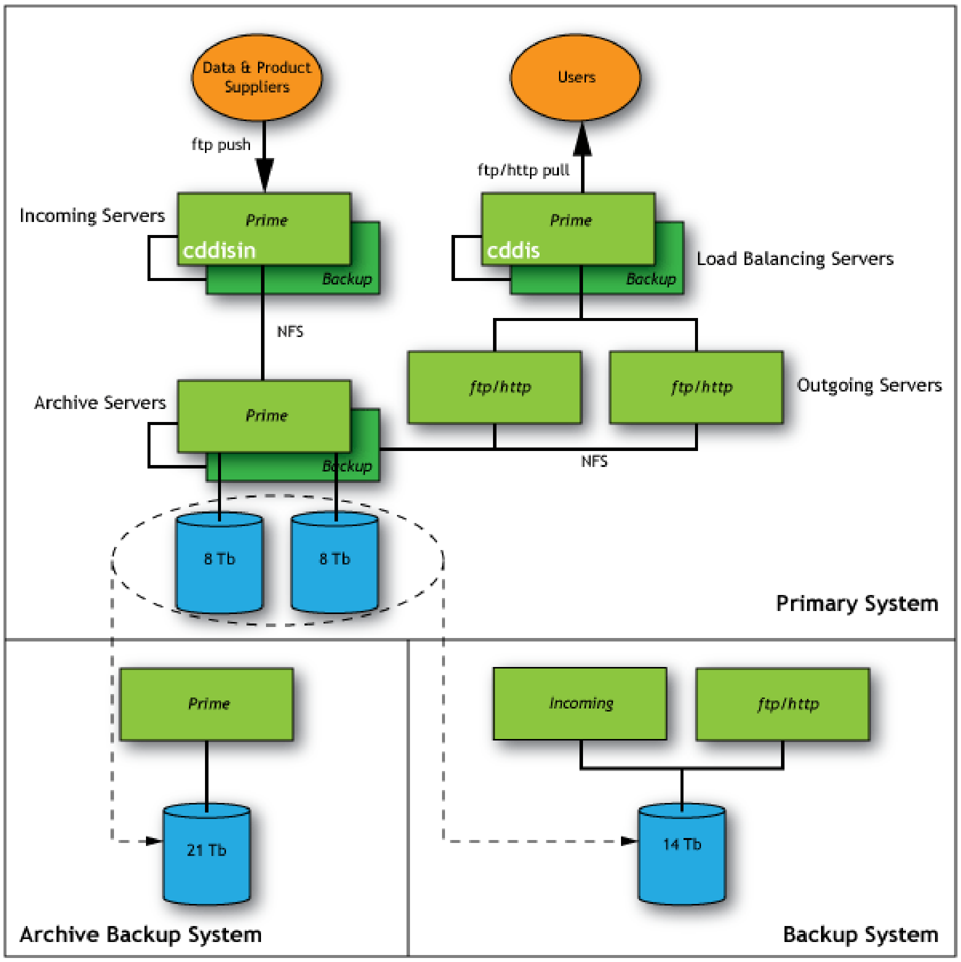
Archive Support: A final portion of the CDDIS archive update process is devoted to utilizing extracted metadata to maintain supporting information, particularly files summarizing the contents of the download area, statistics on the timeliness of the incoming files, etc.

Computer System Upgrade

On June 21, 2010 the CDDIS transitioned operations to a new distributed server environment. This new configuration allows for efficient and timely processing of incoming files as well as enhanced system security by separating user/archive functions. Distinct servers handle incoming data and product files (server cddisin.gsfc.nasa.gov), outgoing ftp and http requests (server cddis.gsfc.nasa.gov), and archive operations to the RAID storage. Servers handle load balancing on incoming queries for files to host cddis.gsfc.nasa.gov.

The archive server manages the RAID storage and its connections to the incoming and outgoing servers. Each server has a "hot spare" which can take over operations should a failure occur with the prime server. Additional RAID storage has been installed to bring the total available storage for the CDDIS archive to nearly 16 Tbytes, plus additional internal storage for processing and database applications. The CDDIS archive increases in size by approximately 1 Tbyte/year; the existing storage will accommodate the archive requirements for the near future. The CDDIS computer system also includes a secondary server for daily backup of the archive. Furthermore, two additional servers and RAID arrays will be set up in the next few months at another GSFC location to provide a complete backup server environment should access to the primary systems be disabled.

In addition to computer hardware changes, the CDDIS replaced its internal database management software (Oracle)



with MySQL. This change required modification to database schemas, supporting software, and report queries.

Figure 5-1. New CDDIS System Architecture.

Contact

Carey Noll
Code 690.1
NASA GSFC
Greenbelt, MD 20771
USA

E-mail: Carey.Noll@nasa.gov
Phone: 301-614-6542
Fax: 301-614-6015

Automated Data Management of SLR Data and Products at the EUROLAS Data Center (EDC)

Christian Schwatke/Deutsches Geodätisches Forschungsinstitut (DGFI)

Introduction

The DGFI operates the EUROLAS Data Center (EDC) since 1994. The main task is to assure that the SLR data and products are available for the stations, analysis centers, combination centers, prediction providers and users. In addition to the data center, the EDC runs an ILRS Operation Center. Tasks of the Operation Center are to quality check and validate SLR observations (both normal point and full-rate data sets) for format errors. In addition, prediction products must be checked by the Operation Center.

System Architecture

The continuously uploading and downloading of data and products by stations, analysis centers, combination centers, prediction providers, and users to the EDC requires an operational system which has as few as possible outages. To achieve this objective the system architecture has been changed.

In the past there was only one operational system available at the EDC. The data holdings were then backed up to an internal server.

The system architecture has been upgraded, making two identical, mirrored systems available. The address of the FTP is *ftp://edc.dgfi.badw.de.* The user will be directed automatically to one of the FTP servers. By using techniques such as port forwarding the failing of individual services (FTP, WWW) can be handled by redirecting requests to different servers. This procedure minimizes the downtime of the EDC.

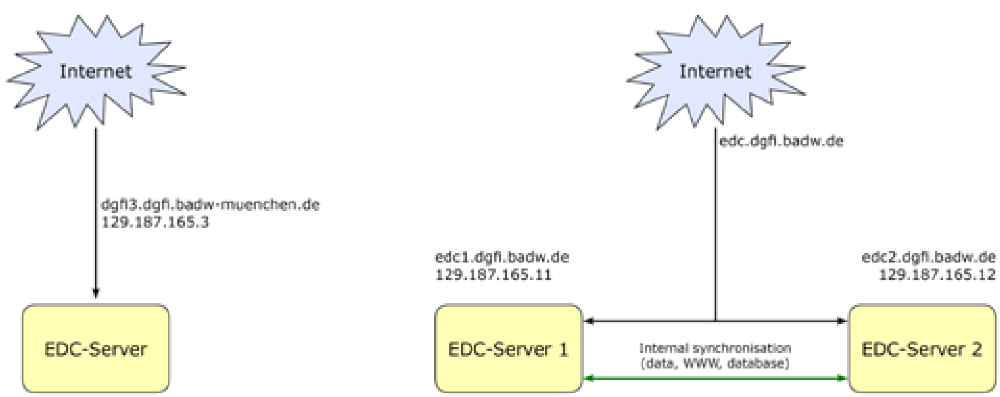


Figure 5-2: Past and current system architecture

Data Flow of EDC within the ILRS

Recently, data exchange within the ILRS infrastructure has become more important, particularly the data transfer between the data centers EDC and CDDIS has changed. Generation of sub-daily predictions for low Earth orbiting (LEO) satellites, such as GRACE, GOCE and others, are necessary. An additional hourly data exchange of data, in the new Consolidated Laser Ranging Data (CRD) format, and predictions, in the Consolidated Prediction Format (CPF), has been realized.

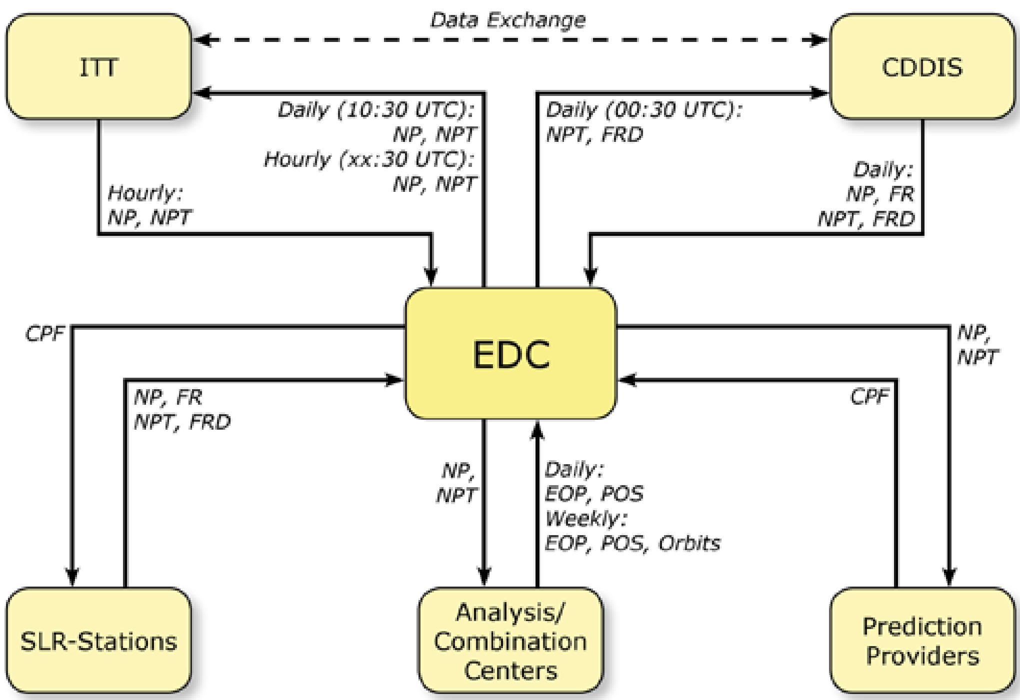


Figure 5-3: Data Flow of EDC within the ILRS

The data flow in the ILRS begins at the SLR-stations, which send normal point and full-rate data sets to the Operations Centers (OCs) located at EDC and NASA. The OCs check all incoming SLR observations. All valid normal point data sets are sent to the NASA Operations Center on an hourly basis. Additionally, a daily file is send to the NASA OC at 10:30 UTC. Independently from NASA, EDC sends daily files with normal point and full-rate data sets to CDDIS at 00:00 UTC. Conversely, the EDC receives hourly normal points from the NASA OC and daily normal point and full-rate data sets from CDDIS.

All SLR observations are available to the ILRS community through the FTP server of the EDC (ftp://edc.dgfi.badw.de). Normal points are used by the Analysis and Combination Centers for the estimation of EOPs, station positions, and orbits. Normal points are also used by Prediction Centers to estimate predictions of satellites. All of these products are also delivered to the EDC and are available on FTP. Additionally, predictions are forwarded via mail to SLR stations.

Data Management at the EDC

The EDC changes the procedure of managing SLR data and products with the introduction of the new Consolidated Laser Ranging Data (CRD) format, the Consolidated Prediction Format (CPF) and the change to a hourly data exchange.

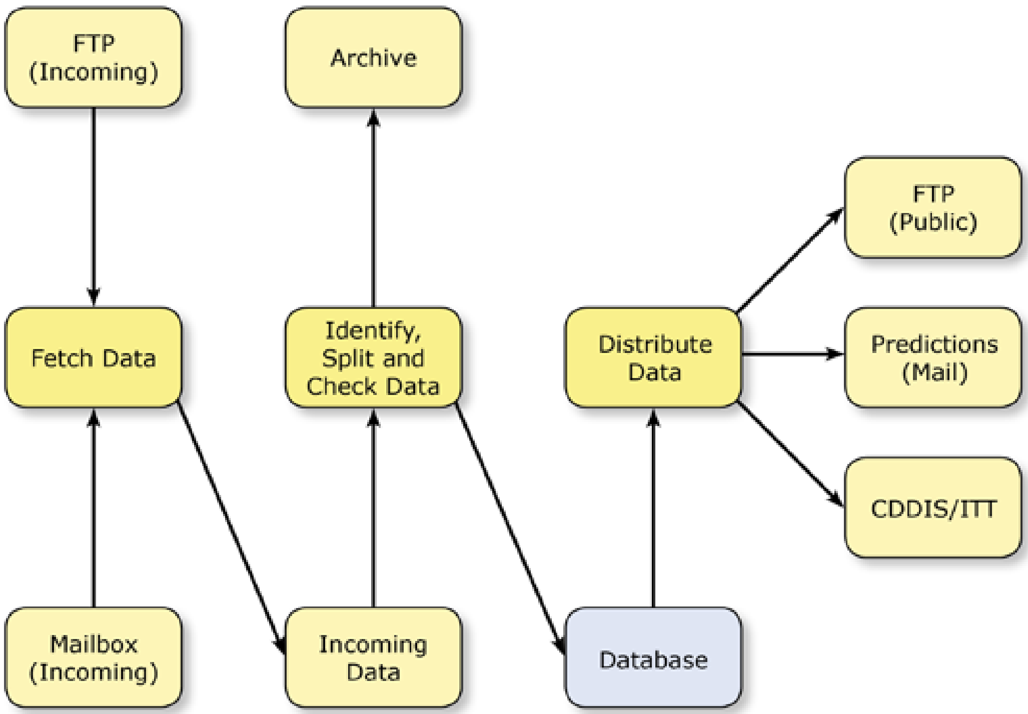


Figure 5-4: Data flow at the EDC

At the EDC, all types of SLR data sets are delivered by mail or ftp. The first step in the data flow is to fetch all data sets from the ftp and mailbox and move them into an incoming folder. Afterwards, a type-identification (NPT, NP, FRD, FR, CPF, etc) occurs. The original data set will be kept untouched with the original timestamp in an archive. Within the Operation Center all data sets are checked to detect format errors. If erroneous data are found, the station manager will be informed to correct them. Multi pass files are split into single pass files. Every single pass file is then saved as a new data set in the database. Each normal point and full-rate data set can be identified by satellite ID, station ID, start date of measurement, end date of measurement, and version. Predictions can be identified by satellite ID, provider, start date, and end date.

The last step in the data flow at the EDC is the distribution of data. All valid data sets are published via FTP. Additionally, CPF predictions are sent to stations as timely as possible after submission. Finally, the data exchange between EDC, the NASA OC, and the CDDIS is executed as described previously.

ILRS Mailing Lists

The EDC maintains the following mailing lists within the ILRS:

- SLR-Mail (*http://slrmail.dgfi.badw.de*)
- SLR-Report (*http://slreport.dgfi.badw.de*)
- Urgent-Mail *(http://urgent.dgfi.badw.de*)
- Rapid Service Mail (http://rapidservicemail.dgfi.badw.de)

SLR-Mail is used to communicate a message to the full ILRS membership (ILRS associates and correspondents). The SLR-Reports are usually computer-generated reports to communicate a periodic status report to interested parties, which are suitable for automated processing. The Urgent-Mail informs station operators about upcoming satellite maneuvers, urgent modification of satellite priorities, etc. The Rapid Service Mail informs stations and analysis centers about detected errors in SLR observations.

Prior to 2011, all mailing lists were managed through scripts. They operated in a semi-automated fashion and required special tags for message handling. A transition to the open source software "Mailman" software was made in 2011. The mailing lists now work automatically and do not require any special tags for processing.

EDC Website

The EDC has redesigned their website (*http://edc.dgfi.badw.de*). This website provides near real time access to the data flow at the EDC. The current status of incoming normal point and full-rate data and predictions are available. If erroneous data sets were submitted, information about the error is available. Statistics about the normal points, full-rate data, and prediction data holdings are also available.

Figure 5-5: Website of EDC

Contact

Christian Schwatke
E-mail: schwatke@dgfi.badw.de
Deutsches Geodätisches Forschungsinstitut (DGFI)
Alfons-Goppel-Str. 11
80539 München, Germany

INFRASTRUCTURE SUPPORT

New CRD Format

Randy Ricklefs/U. Texas at Austin/CSR

Due to the one-way laser ranging support of the Lunar Reconnaissance Orbiter (LRO) mission, and the growing number of stations with lasers firing at a kilohertz rate, the Data Formats and Procedures Working Group has rewritten the formats for the ILRS full-rate, normal point, and sampled engineering data types. The older formats do not allow for many of the fields or field sizes required for ranging to transponders. In addition, the current full-rate format is too cumbersome for the amount of data produced by kilohertz laser ranging. The new format encompasses all three data types for SLR, LLR, and transponder targets. The Consolidated Laser Ranging Data (CRD) format uses the same building block approach as the Consolidated Prediction Format (CPF), which allows modularity, flexibility, and expandability. Since the CRD format is considerably more complicated than the old formats, a process was developed by which the ILRS Operations Centers (OCs) at EDC and NASA/HTSI and the AWG would validate CRD normal points from each station. Once a station's data are validated, the station normally submits data only in the CRD format. As of the end of 2010, 29 stations were sending normal point to the OCs in the CRD format, with 25 having passed the validation tests. At the same time, many stations were producing full-rate data in the CRD format. To assist in implementing the new format, sample code is provided on the ILRS website.

Satellite Predictions

There are now ten centers that provide SLR predictions on a regular basis (see Table 5-1).

Table 5-1. Satellite Prediction Providers (as of December 2010)

Center	Interval	Satellites
CNES	Daily	Jason
CODE	Daily	GLONASS, GOCE, GPS
ESOC	Daily	CryoSat-2, Envisat, ERS-2, GIOVE, GOCE
FDF	Daily	LRO
GFZ	Sub-daily	GRACE, CHAMP, TerraSAR-X
HTSI	Daily	Ajisai, BE-C, BLITS, COMPASS-M1, CryoSat-2, Envisat, ERS-2, Etalon, GIOVE, GLONASS, GPS, Jason, LAGEOS, LARETS, Starlette, Stella
JAXA	Daily	Ajisai, LAGEOS, QZS
MCC	Daily	BLITS, LARETS
NSGF	Daily	Ajisai, BE-C, Envisat, ERS-2, Etalon, Jason, LAGEOS, LARETS, Starlette, Stella
SAO	Sub-weekly	COMPASS-M1
UTX	Daily	Moon

The Consolidated laser ranging Prediction Format (CPF) is used within the ILRS for ranging to Earth satellites and the Moon, and for transponder ranging to planets and interplanetary spacecraft. In the process of developing the format, sample software was developed to allow standardizing prediction interpolators used at the stations. Since 2006, the tracking of very low Earth orbit satellites has increased significantly with the sub-daily distribution of the new, high quality CPF predictions. Many stations have also been able to range to the Lunar Reconnaissance Orbiter, the first target in lunar orbit and the first one-way transponder mission to be tracked.

The ILRS is encouraging stations to use the mission-provided or -sanctioned predictions for satellites where they are available. Some of the recent missions have periodic maneuvers or drag compensation capability, and some also have GPS data from on-board receivers to enhance the SLR predictions. Since the missions have the most up-to-date information of this type, they are in the best position to keep predictions current and accurate.

Satellite Priorities

The ILRS tries to order its tracking priorities (shown in Table 5-2) to maximize the utility to the users of ILRS data. Nominally tracking priorities decrease with increasing orbital altitude and increasing orbital inclination (at a given altitude). Priorities for some satellites are then increased to intensify support for active missions (such as altimetry), special campaigns (such as satellite in eclipsing orbit), and post-launch intensive tracking campaigns. Some slight reordering may then be given missions with increased importance to the analysis community. Some tandem missions (e.g., GRACE-A and -B) may be tracked on alternate passes at the request of the sponsor. Stations may also adjust priorities to accommodate local conditions such as system capabilities, weather, and special program interests.

Table 5-2. Satellite and Lunar Tracking Priorities (as of December 2010)

Satellite Priorities					
Priority	**Satellite**	**Sponsor**	**Altitude (km)**	**Inclination (degrees)**	**Comments**
1	GOCE	ESA	295	96.7	
2	GRACE-A/B	GFZ, JPL	485-500	89	Tandem mission

3	CryoSat-2	ESA	720	92	
4	TanDEM-X	Infoterra/DLR/ GFZ/CSR	514	98	Tandem with TerraSAR-X
5	TerraSAR-X	Infoterra/DLR/ GFZ/CSR	514	97.44	Tandem with TanDEM-X
6	Envisat	ESA	796	98.6	Tandem mission with ERS-2
7	ERS-2	ESA	800	98.6	Tandem mission with Envisat
8	BLITS	Russia	832	98.77	
9	Jason-1	NASA, CNES	1,350	66.0	Tandem mission with Jason-2
10	Jason-2	NASA, CNES, Eumetsat, NOAA	1,336	66.0	Tandem mission with Jason-2
11	Larets	IPIE	691	98.2	
12	Starlette	CNES	815-1,100	49.8	
13	Stella	CNES	815	98.6	
14	Ajisai	JAXA	1,485	50	
15	LAGEOS-2	ASI, NASA	5,625	52.6	
16	LAGEOS-1	NASA	5,850	109.8	
17	QZS-1	JAXA	32,000-40,000	45	WPLTN tracking only
18	BE-C	NASA	950-1,300	41	
19	Etalon-1	Russian Federation	19,100	65.3	
20	Etalon-2	Russian Federation	19,100	65.2	
21	COMPASS-M1	China	21,500	55.5	
22	GLONASS-115	Russian Federation	19,400	65	Replaced GLONASS-99 (31-Mar-2009)
23	GLONASS-120	Russian Federation	19,400	65	Replaced GLONASS-109 (06-Apr-2010)
24	GLONASS-102	Russian Federation	19,400	65	Replaced GLONASS-89 (04-May-2007)
25	GPS-36	U.S. DoD	20,100	55.0	
26	GIOVE-A	ESA	29,601	56	
27	GIOVE-B	ESA	23,916	56	
28	GLONASS-109	Russian Federation	19,400	65	
29	GLONASS-110	Russian Federation	19,400	65	
30	GLONASS-118	Russian Federation	19,400	65	

Lunar 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

Tracking priorities are formally reviewed semi-annually by the ILRS Governing Board. Updates are made as necessary. The Central Bureau communicates these updates to the ILRS stations.

Restricted Tracking on Vulnerable Satellites

Randy Ricklefs/U. Texas at Austin/CSR

During the last few years, network procedures have been implemented to protect satellites that are vulnerable to laser radiation. Satellites such as ICESat and ALOS have optical sensors aboard that could be damaged. Restricted satellite missions may opt to request one, two, or all of the possible restrictions for their mission, but the numbers 1 and 6 below are required procedures. The procedures include:

- predictions are sent to only participating (qualified) stations;
- stations are restricted to a maximum ranging elevation to protect fixed nadir pointing sensor(s);
- missions provide allowable pass segment files to carefully define tracking and non-tracking periods;
- stations are constrained by a mission-provided, Web-accessible GO/NO-GO flag which allows immediate (within 5 minutes) cessation of all network tracking of the target;
- stations can also be constrained to a mission-defined maximum power delivered to the spacecraft; and
- participation is limited to trusted stations that have demonstrated the ability to handle the restrictions (from 2-5 above) required by the mission.

A questionnaire regarding each station's ability to handle these various restrictions was circulated in 2009, with 31 stations responding. A total of 15 stations had the capability of handling all but the power restrictions. At that time, only 2 stations had automatic power control, although more could accomplish control manually. Another 10 were planning to add at least some of these capabilities, often on an as-needed basis. The latest information by station can be viewed through the Stations section of the ILRS website at *http://ilrs.gsfc.nasa.gov/network/stations/index.html*. Regardless of these findings, each mission requiring tracking restrictions should plan and conduct tests of their chosen sub-network with a non-restricted satellite.

During this period ICESat and LRO used the GO/NO-GO flag. ICESat also imposed elevation restrictions, and LRO required a power level restriction. Both provided predictions to a select sub-network.

Improved Normal Point Formulation Strategy

Peter Dunn

The original Herstmonceux normal point definition specifies a standard normal point interval (SNPI) for each satellite based on altitude. Normal points start and stop at prescribed times and the normal point epoch is taken as the epoch of the central point in the normal point full rate (FR) population. This definition was adopted based on our then current firing rates of 5 – 10 Hz.

As SLR systems move to higher repetitions rates (0.1 – 2 KHz) and more automation we need to revisit the definition of our normal points or at least make a provision for those systems that performance could be greatly enhanced with more flexibility. In particular, systems with higher repetition rates can use shorter normal point intervals, greatly improving satellite interleaving capability. In addition, stations in dense regions of the network (e.g. Europe, China, etc) may be requested to range differently from stations in sparse regions (South Africa, Tahiti, etc) to some satellites to enhance coverage. Stations in dense regions may be asked to share coverage on some satellites while those in sparse may have to time share among satellites more efficiently.

GGOS sets a goal of 1mm precision from the best performing systems. Normal points from each stations should be structured to extract the maximum amount of information that a station can provide; so structure will depend upon laser pulse repetition rate, pulse width, system noise, receiver characteristics, target signature, etc.

A Normal Point Study Group has been established to recommend modifications to the Herstmonceux procedure to better optimize our ranging resources. The over riding theme however is that it be as uncomplicated as possible.

The work of the Study Group is still underway, but a procedure being considered is the following:

1. A Normal Point is completed when either 1000 valid FR points have been taken, or the SNPI has been reach, whichever comes first;
2. If a station achieves 1000 valid FR points in less that the SNPI, it can move on to another satellite;
3. If the full SNPI has been required to populate the normal point, ranging can continue on the current satellite or another satellite;
4. A station should not return to Satellite 1 until at least the SNPI has elapsed;
5. New normal points can start at any time;
6. The epoch of the normal point is that of a central FR data point in the normal point population.

When the Study Group deliberations have been completed, the procedure will be released to the Analysis Working Group for assessment