Consolidated Laser Ranging Data Format (CRD)

Version 0.26

R. L. Ricklefs
The University of Texas at Austin / Center for Space Research
C. J. Moore
EOS Space Systems Pty. Ltd.
For the ILRS Data Formats and Procedures Working Group

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Abstract

Due to recent technology changes, the existing International Laser Ranging Service (ILRS) formats for exchange of laser fullrate, sampled engineering and normal point data are in need of revision. The main technology drivers are the increased use of kilohertz firing-rate lasers which make the fullrate data format cumbersome, and anticipated transponder missions, especially the Lunar Reconnaissance Orbiter (LRO), for which various field sizes are either too small or non-existent. Rather than patching the existing format, a new flexible format encompassing the 3 data types and anticipated target types has been created.

Introduction

The purpose of the Consolidated Laser Ranging Data Format (CRD) is to provide a flexible, extensible format for the ILRS fullrate, sampled engineering, and normal point data. The primary motivations for creating a new format at this time is to allow for transponder data, and to handle high-repetition-rate laser data without unnecessary redundancy. This format is based on the same features found in the ILRS Consolidated Prediction Format (CPF), including separate header and data record types assembled in a building block fashion as required for a particular target.

There are 3 separate sections to the data format: 1) the header section which contains data on the such topics as station, target, and start time; 2) the configuration section containing an expanded version of data previously described by the System Configuration Indicator (SCI) and system CHange Indicator (SCH) fields; and 3) the data section containing laser transmit and receive times, and other highly dynamic information. The data headers are fixed format and similar in content to those of the CPF files. The configuration and data records are free format with spaces between entries. Records can be added as needed for the specific data types and at frequencies commensurate with the data rate. For example, at a 2 kHz ranging rate, meteorological data and pointing angles are commonly read far less frequently than the ranges. Note that 1 way out-bound, 1 way in-bound, and 2 way ranges could all appear within one file. Also note that multiple colors could appear in one file.

Advantages of this format over the current ILRS formats are as follows;

Flexibility. The data files can be simple and compact for kiloHertz ranging or comprehensive for more complex data structures, as appropriate.

The building block structure with multiple record type allows for including and omitting certain records types as needed by a station or target.

Configuration descriptions are addressed in a more explicit, logical and extensible manner than the current format.

A single integrated format can be used for current and future data and target types.

Multiple color data, multiple ranging modes (transponder one- and two-way ranges) and multiple configurations can be included naturally within a single data file.

The format can be expanded in the future as needs expand without abandoning the entire format.

All data types (full rate, sampled engineering, and normal point) can be managed in a single file if desired, e.g., for archival and reference purposes.

Extensibility to the eXtensible Markup Language (XML) is provided for in the design.

Fields in the Configuration sections are compatible with the SLR Engineering Data File (EDF) format.

When data is converted from an old format to the CRD format, there will be fields (such as skew and kurtosis) that do not exist in the old format. In these cases, unless noted otherwise, numerical fields in the new format should be set to “-1” to indicated “no information”. Character fields without information should be filled with “na” for “Not Available”.

In the following pages, sections 1 – 3 provide a description and discussion of the specific file sections and record types. Following that, section 4 gives examples of the file structure for various types of data. Section 5 addresses file naming conventions. Section 6 provides some real-world examples of the new format, while section 7 provides web references to formats and “official lists.” Finally, Section 8 provides definitions of abbreviations.

1. Header Records

Fields in header records are defined according to the following format specifications (in contrast to data records which will have free format fields that are delimited by white space). Upper and lower case characters are both acceptable: e.g., “H1” or “h1”; “CRD” or “crd” in H1.

White spaces are allowed (where appropriate) in header record fields since these are fixed format.

1.1. Format Header

The format header describes information relating to the file: e.g. the version of the format used, time of production etc.

1.1.1. Format:

1-2	A2	Record Type (= "H1")
4-6	A3	"CRD" (Consolidated Ranging Data format)
8-9	I2	Format Version
11-14	I4	Year of file production
16-17	I2	Month of file production
19-20	I2	Day of file production
22-23	I2	Hour of file production (UTC)

1.1.2. Notes

There must be one and only one format header record in the file and it must be the first record.

1.2. Station Header

The station header describes information relating to the station or site collecting this laser data.

1.2.1. Format:

1-2	A2	Record Type (= "H2")
4-13	A10	Station name from official list(e.g., "MOB7 ", "MLRS ")
15-18	I4	Crustal Dynamics Project Pad Identifier
20-21	I2	Crustal Dynamics Project 2-digit system number
23-24	I2	Crustal Dynamics Project 2-digit occupancy sequence number
26-27	I2	Station Epoch Time Scale - indicates the time scale reference. 4 = UTC (GPS) 7 = UTC (BIH) 1-2, 5-6, 8-9 = reserved for compatibility with earlier data using obsolete time scales.

10 and above = UTC (Station Time Scales)

1.2.2. Notes

For station-created files, there must be one and only one station header record in the file and it must be the second record. Data centers may combine files.

The “Station Time Scales” option is needed to describe the time scale that accommodates the added precision of fire and return times for transponder ranging. The other time scales are not (yet) good to 1 picosecond, so some other ad hoc time scale must be used. Since the time scale techniques will evolve with time, there are many indicators (10-99) available to describe which time scale is used. In fact, these indicators may be station or experiment dependent.

The Crustal Dynamics Project Pad, site, and occupancy sequence number are often combined into the “CDDIS SOD” found in the official pad and code list mentioned in the introduction to this document.

1.3. Target Header

The target header describes static information relating to the target, whether it is a satellite, lunar or spacecraft target.

1.3.1. Format:

1-2	A2	Record Type (= "H3”)
4-13	A10	Target name from official list(e.g., "Ajisai", "GPS35")
15-22	I8	ILRS Satellite Identifier (Based on COSPAR ID)
24-27	I4	SIC (Satellite Identification Code)
29-36	I8	NORAD ID
38-38	I1	Spacecraft Epoch Time Scale (transponders only)
		0 = Not used.
		1 = UTC
		2 = Spacecraft Time Scale

1.3.2. Notes

There must be at least one target header (and associated child records) in a file but there could possibly be more, e.g. for accumulating normal point data for many targets over a period (e.g. one day) for transmission to data centres.

COSPAR ID to ILRS Satellite Identification Algorithm:
COSPAR ID Format: (YYYY-XXXA)

YYYY is the four digit year of when the launch vehicle was put in orbit
XXX is the sequential launch vehicle number for that year

A is the alpha numeric sequence number within a launch
Example: LAGEOS-1 COSPAR ID is **1976-039A**
Explanation: LAGEOS-1 launch vehicle was placed in orbit in 1976; was the 39th launch in that year; and LAGEOS-1 was the first object injected into orbit from this launch.

ILRS Satellite Identification Format: (YYXXXAA), based on the COSPAR ID

Where YY is the two digit year of when the launch vehicle was put in orbit
Where XXX is the sequential launch vehicle number for that year
AA is the numeric sequence number within a launch
Example: LAGEOS-1 ILRS Satellite ID is **7603901**

1.4. Session (Pass) Header

The session/pass header describes information relating to the period over which the data is collected. For normal satellite targets this is generally each pass, but could be associated with pass segments. For geostationary satellites and distant targets, it must be related to time segments as defined by the station. It will be necessary to specify and hence enforce that certain parameters or conditions remain constant or static during a session.

The session header is the place to indicate what type of data records follow – this will enforce data records to be provided in blocks of consistent data rather than allowing sampled engineering, full rate and normal point records to be randomly intermingled.

Hence there must be a Session Header preceding each block of data and there may be more than one Session Header for a given pass or segment if different types of data follow.

1.4.1. Format:

1-2	A2	Record Type (= "H4”)	
4-5	I2	Data type	
		0 = full rate	
		1 = normal point	
		2 = sampled engineering	
7-10	I4	Starting Year	
12-13	I2	Starting Month	
15-16	I2	Staring Day	
18-19	I2	Starting Hour (UTC)	
21-22	I2	Starting Minute (UTC)	
24-25	I2	Starting Second (UTC)	
27-30	I4	Ending Year	(Set ending date and time fields to “0” if not available.)
32-33	I2	Ending Month	
35-36	I2	Ending Day	

38-39 I2 Ending Hour (UTC)

41-42 I2 Ending Minute (UTC)

44-45 I2 Ending Second (UTC)

47-48 I2 A flag to indicate the data release:
- 0: first release of data
- 1: first replacement release of the data,
- 2: second replacement release, etc

50-50 I1 Tropospheric refraction correction applied indicator
- 0 = False (not applied)
- 1 = True (applied)

52-52 I1 Center of mass correction applied indicator
- 0 = False (not applied)
- 1 = True (applied)

54-54 I1 Receive amplitude correction applied indicator
- 0 = False (not applied)
- 1 = True (applied)

56-56 I1 Station system delay applied indicator
- 0 = False (not applied)
- 1 = True (applied)

58-58 I1 Spacecraft system delay applied (transponders) indicator
- 0 = False (not applied)
- 1 = True (applied)

60-60 I1 Range type indicator
- 0 = No ranges (i.e. transmit time only)
- 1 = 1 way ranging
- 2 = 2 way ranging
- 3 = Receive times only
- 4 = Mixed (for real-time data recording)

Important: If Range type indicator is **not** set to two-way (2), all corrections must be written as one way quantities. Specifically, this applies to range, calibration, refraction correction, center of mass correction, as well as all RMS and other statistical fields.

1.4.2. Notes

For normal point records, stations generating the file must set the Centre of Mass and Refraction Applied flags to false and provide data consistent with these flags. The format however allows data to be provided where normal point data have these corrections applied e.g. for special purpose users or for use by data centres themselves.

Ending time may be cumbersome to compute if data is being written directly into the CRD format in real-time. In this case the ending date and time fields may be zero-filled.

1.5. End of Session Footer

1.5.1. Format

1-2	A2	Record Type (= "H8")

1.5.2. Notes

Include even if it is immediately followed by end of file footer.

1.6. End of File Footer

1.6.1. Format

1-2	A2	Record Type (= "H9")

1.6.2. Notes

If an end-of-file footer is missing the implication is that the file has been truncated and has therefore been corrupted. One response could be to request a retransmission of the file.

2. Configuration Records

Configuration records will hold static data that represents station specific configuration information used while collecting the data stored in this file. All fields must be separated by spaces, and white spaces are not allowed within record fields. These records are free format and rely on white spaces for parsing. The field types (e.g., I5, F12.5) are suggestions, and should be sized according to the stations' needs.

While detailed configuration records are strongly encouraged and are a vital part of the CRD format, the minimum requirement is a "C0" record containing the Transmit Wavelength and the System Configuration ID, and the "60" Compatibility Record. The "60" record is not required if records C1-C3 are included, although it may be useful until the format is fully implemented. Record "C4" is always required for transponder data.

The "detail type" field in the configuration records allows for future expansion of the configuration record format. At this time, this field will always have the value "0".

2.1. System Configuration Record

The system configuration record provides a means for identifying all significant components of a system in operation during collection of the data records contained within this file. This record will be an extensible list of configuration records of components deemed necessary to characterize the system at any given time during which data records are collected.

2.1.1. Format:

A2(1-2)	Record Type (= "C0").
A1(3)	Detail Type (= "0").
F10.3	Transmit Wavelength (nanometers)
A4	System Configuration id (unique within the file)
A4	Component A configuration id (e.g. detector configuration id)
A4	Component B configuration id (e.g. laser configuration id)
A4	Component C configuration id (e.g. local timing system configuration id)
A4	Component D configuration id (e.g. transponder configuration id)

Repeat as required.

2.1.2. Notes

The use of configuration records replaces the current SCI and SCH (but not the station site log) files. To access information currently contained in the SCH file, one should use the date and time as a key and extract the information from station site log files which should be maintained to provide such data. The SCI file is totally replaced by the records in the current file.

The Transmit Wavelength represent the wavelength of the laser beam as transmitted to the atmosphere and is thus common to many of the station subsystems. Hence it is included explicitly in this record.

One advantage of this is that the association of data records to wavelength used is more direct.

The file ***must*** contain at least one Configuration Header. If there are multiple system configurations used when generating the data records contained within the file, then there should be multiple system configuration headers in the file. These should appear after the associated component configuration records have all been defined.

A standard enumerated list of components for many of the configuration fields needs to be maintained. This includes, for example, detector type, laser type, timer. Any input would be appreciated!

2.2. Laser Configuration Record

The file should contain at least one Laser Configuration record. If multiple wavelengths are used or there are significant changes to any of the other parameters within the data sets in the file, then there must be appropriate Laser Configuration records for each wavelength or configuration used.

2.2.1. Format:

A2(1-2)	Record Type (= "C1").
A1(3)	Detail Type (= "0").
A4	Laser Configuration id (unique within the file)
A10	Laser Type (e.g. “Nd-Yag”)
F10.2	Primary wavelength (nm)
F10.2	Nominal Fire Rate (Hz)
F10.2	Pulse Energy (mJ): record when this fields changes by 10%
F6.1	Pulse Width (ps): record when this fields changes by 10%
F5.2	Beam Divergence (arcsec)
I4	Number of pulses in outgoing semi-train

2.2.2. Notes

Note that the primary wavelength is used here, e.g. use 1064 for a Nd-Yag laser even though only 532 is used.

Most fields are expected to be static for a given laser. Pulse energy and width should trigger the writing of a new record whenever they change by 10%.

2.3. Detector Configuration Record

The file should contain at least one Detector Configuration record. If multiple wavelengths are used or there are significant changes to any of the other parameters within the data sets in the file, then there must be an appropriate Detector Configuration record for each wavelength or configuration used.

2.3.1. Format:

A2(1-2)	Record Type (= "C2").

A1(3) Detail Type (= "0").

A4 Detector Configuration id (unique within the file)

A10 Detector Type (e.g.”SPAD”, “CSPAD”, “MCP”, “APD”, GeDiode” …)

F10.3 Applicable wavelength (nm)

F6.2 Quantum efficiency at applicable wavelength (%).

F5.1 Applied voltage (V)

F5.1 Dark Count (kHz)

F5.1 Output pulse type (ECL, TTL, photon-dependant, …)

F5.1 Output pulse width (ps)

F5.2 Spectral Filter (nm)

F5.1 % Transmission of Spectral Filter

F5.1 Spatial Filter (arcsec)

A10 External Signal processing

2.3.2. Notes

Most fields are expected to be static for a given detector. Spatial and spectral filters changes should be recorded when they change by 10% (for continuously variable filters), or whenever they change (for discrete filters).

2.4. Timing System Configuration Record

The file should contain at least one station Timing System Configuration record. If multiple timing systems are used, then there must be an appropriate Timing System Configuration record for each system used.

2.4.1. Format:

A2(1-2) Record Type (= "C3").

A1(3) Detail Type (= "0").

A4 Timing System Configuration id (unique within the file)

A20 Time Source (e.g.”Truetime XLi”, “Truetime XL-SD”, “Datum 9390”, “HP 58503A”, “TAC”,…..)

A20 Frequency Source (e.g. “Truetime OCXO”, “CS-4000”,)

A20 Timer (e.g. “MRCS”, “SR620”, “HP5370B”, “Dassault”, ”Other” …)

A20 Timer Serial Number (for multiple timers of same model)

F6.1 Epoch delay correction (ps).

2.4.2. Notes

Most of the fields in this record should effectively be pointers to items in the Station Log File where associated static data on each device can be found. The epoch delay correction provides a measure of the propagation delay between the Time Source output and the point at which the timing epochs are registered. For example, in some systems, a 1PPS signal is used to latch second boundaries, However there must be some correction applied for the transmission delay between the source of the 1PPS signal and the timer system.

2.5. Transponder (Clock) Configuration Record

The transponders header describes static information relating to certain transponders

2.5.1. Format:

A2(1-2) Record Type (= "C4").

A1(3) Detail Type (= "0").

A4 Transponder Configuration id (unique within the file)

F20.3 Estimated Station UTC offset (nanoseconds)

F11.2 Estimated Station Oscillator Drift (UTC/station clock) in parts in 10^{15}.

F20.3 Estimated Transponder UTC offset (nanoseconds)

F11.2 Estimated Transponder Oscillator Drift (UTC/spacecraft clock) in parts in 10^{15}

F20.12 Transponder Clock Reference Time. (seconds, scaled or unscaled)

I1 Station offset and drift applied indicator.

0 = False (not applied)

1 = True (applied)

I1 Spacecraft offset and drift applied indicator.

0 = False (not applied)

1 = True (applied)

I1 Spacecraft time simplified

0 = False

1 = True

2.5.2. Notes

Note that standard sense used in all time and frequency metrology must be followed, e.g. local station offset is (UTC – local station).

A transponder configuration record is required only if the target contains a transponder or time transfer equipment.

To convert from spacecraft master clock units and timescale,

$$t_{UTC} = t_{master} + (t_{master} - t_o) * 10^{-15} * \text{Oscillator Drift} + \text{UTC offset}$$

where t_o is Transponder Clock Reference Time, the time at which master clock was calibrated against

UTC (somehow), and the UTC offset is (UTC-master) at time t_o.

For the space craft time simplified mode (used for LRO), t_o has already been removed from t_{master} to allow passing of a much smaller number. The Transponder Clock Reference Time field is filled but only used for reference. The equation then becomes

$$t_{UTC} = t_{master} + (t_{master}) * 10^{-15} * \text{Oscillator Drift} + \text{UTC offset}.$$

The conversion for the station clock is analogous.

A new record should be written whenever a field changes value.

3. Data Records

Data records contain non-static data and hence they all will contain a timestamp field. All fields ***must*** be separated by spaces, and white spaces are not allowed within data fields. These records are free format and rely on white spaces for parsing. The field types (e.g., I5, F12.5) are suggestions, and should be sized according to the target's needs and the station's precision. There will be no unused or undefined fields.

3.1. Range Record (Full rate, Engineering)

The full rate range record contains single-shot measurement data. Generally only accepted signal data will be included but engineering data and low-quality (see quality and filter flags) may contain noise data as well. The file will contain blocks of one or more range records corresponding to a consistent format and system configuration.

3.1.1. Format:

A2(1-2) Record Type (= "10")

F18.12 Fire time seconds of day (typically to 100 ns for SLR/LLR or 1 picosecond for transponder/T2L2). For transponders, station clock correction may be applied.

F18.12 Range in seconds (none, 1-, or 2-way depending on range type indicator); or (for Epoch Event 5) spacecraft receive time in units of the spacecraft master clock, or seconds if “Spacecraft offset and drift applied indicator” is true. Range may be corrected for station system delay; receive time may be corrected for spacecraft system delay and/or clock correction.

A4 System configuration id.

I1 Epoch Event - indicates the time event reference.

Currently, only 1 and 2 are used for laser ranging data.

0 = Ground receive time (at System Reference Point - SRP) (2 way)

1 = Spacecraft bounce time (2 way)

2 = Ground transmit time (at SRP) (2 way)

3 = Spacecraft receive time (1 way)

4 = Spacecraft transmit time (1 way)

5 = Ground transmit time (at SRP) and spacecraft receive time (1 way)

6 = Spacecraft transmit time and ground receive time (at SRP) (1 way)

I1 Filter Flag

0=unknown

1=noise

2=data

I1 Detector channel

0 = not applicable or “all”

1-4 for quadrant

1-n for many channels

I5 Receive Amplitude - a positive linear scale value.

3.1.2. Notes

Receive signal strength is not in the current normal point format, but is left in this record for compatibility with engineering quick look and full rate data.

Format allows multiple color data to be included in the same file, with separate normal point statistics, etc.

As noted above, transmit time only, receive time only, 1-way, and 2-way ranges etc. can appear in the same file, to accommodate transponders.

Note that station transmit and receive times are nominally with respect to the system reference point (SRP) which will in many cases be the telescope invariant point. This requires a knowledge of both the transmit delay and receive delay, which is critical for transponder ranging. It is less critical for normal satellite (two-way) ranging since errors in distributing the system delay to these components will cancel.

It should be remembered that full rate data should include a swathe of data around the station assessed signal, and assessed noise and signal data be indicated using the filter flag. The noise/data flag should initially be set based on on-site processing.

3.2. Range Record (Normal Point)

The normal point range record contains accepted measurement data formed into normal point bins. The file will contain blocks of one or more range records corresponding to a consistent format and system configuration.

3.2.1. Format:

A2(1-2) Record Type (= "11")

F18.12 Seconds of day (typically to < 100ns for SLR/LLR or <1 ps for transponders). Station clock corrections should be applied for all targets.

F18.12 Range in seconds (none, 1-, or 2-way depending on range type indicator); or (for Epoch Event = 5) spacecraft receive time in units of the spacecraft master clock, or seconds if “Spacecraft offset and drift applied indicator” is true. Range should be corrected for station system delay; receive time may be corrected for spacecraft system delay and/or clock correction.

A4 System configuration id.

I1 Epoch Event - indicates the time event reference.

Currently, only 1 and 2 are used for laser ranging data.

0 = Ground receive time (at SRP) (2 way)

1 = Spacecraft bounce time (2 way)

2 = Ground transmit time (at SRP) (2 way)

3 = Spacecraft receive time (1 way)

4 = Spacecraft transmit time (1 way)

5 = Ground transmit time (at SRP) and spacecraft receive time (1 way)

6 = Spacecraft transmit time and ground receive time (at SRP) (1 way)

I4 Normal point window length (seconds)

I6 Number of raw ranges (after editing) compressed into the normal point.

F9.1 Bin RMS from the mean of raw accepted range values minus the trend function (ps)

F7.3 Bin skew from the mean of raw accepted range values minus the trend function.

F7.3 Bin kurtosis from the mean of raw accepted range values minus the trend function.

F9.1 Bin peak – mean value (ps)

F5.1 Return rate (%) for SLR or signal to noise ratio, in units of 0.1 for LLR.

3.2.2. Notes

Note that station transmit and receive times are nominally with respect to the system reference point (SRP) which will in many cases be the telescope invariant point. This requires a knowledge of both the transmit delay and receive delay, which is critical for transponder ranging. It is less critical for normal satellite (two-way) ranging since errors in distributing the system delay to these components will cancel.

If there are too few data points to assess pass rms, skew, or kurtosis, put “-1” in the field. It is left to the station’s discretion, subject to ILRS directives, whether to include normal points having few data points.

3.3. Range Supplement Record

The range supplement range record contains optional range data and will be interspersed with range data to which it is associated. If this record is used, then it should be created whenever there is a ***significant*** change to one or more fields.

3.3.1. Format:

A2(1-2) Record Type (= "12")

F18.12 Seconds of day.

A4 System configuration id.

F6.1 Tropospheric refraction correction (picoseconds)

F6.4 Target Center of Mass Correction (meters)

F5.2 Neutral Density (ND) filter value

F8.4 Time bias applied (seconds)

3.3.2. Notes

None.

3.4. Meteorological Record

This data record contains a minimal set of meteorological data. At least one record must appear in the data file.

3.4.1. Format:

A2(1-2) Record Type (= "20")

F18.12 Seconds of day (typically to 1 milllisec)

F7.2 Surface Pressure (mbar).

F6.2 Surface Temperature in degrees Kelvin.

F4.0 Relative Humidity at Surface in %

3.4.2. Notes

Meteorological records should only be written when one of the fields changes “significantly”. The criteria should be at least 2 times the least significant bit of the sensor, to prevent noise in the lowest bit from constantly producing new records. In addition the criteria should require new records whenever pressure changes by 0.1 mb, temperature changes by 0.1 K, or humidity changes by 5%.

3.5. Meteorological Supplement Record

This data record contains an (optional) supplement set of meteorological data. A file must contain at least one meteorological record and may contain one or more meteorological supplement records.

3.5.1. Format:

A2(1-2) Record Type (= "21")

F18.12 Seconds of day (typically to 1 milllisec)

F5.1 Wind speed (m/s)

F5.1 Wind direction (degrees azimuth, north is zero)

A4 Precipitation type (“rain”, “snow”, “fog”, “fine” ...TBD)

I3 Visibility (km)

I3 Sky Clarity (ie zenith extinction coefficient)

I2 Atmospheric seeing (arcsec)

I2 Cloud cover (%)

3.5.2. Notes

Meteorological records should only be written when one of the fields changes “significantly”. The criteria should be at least 2 times the least significant bit of the sensor, to prevent noise in the lowest bit from constantly producing new records.

Please comment on the choice of fields here!

3.6. Pointing Angles Record

This record contains telescope or beam director pointing (azimuth and elevation) angles, and is optional for normal point data sets. If it is used, the source and nature of this data must be provided.

3.6.1. Format:

A2(1-2) Record Type (= "30")

F18.12 Seconds of day (typically to 1 milllisec)

F8.4 Azimuth in degrees

F8.4 Elevation in degrees

A1 Direction flag

0 = transmit & receive

1 = transmit

2 = receive

A1 Angle Origin Indicator

0 = unknown

1 = computed

2 = commanded (from predictions)

3 = measured (from encoders)

A1 Refraction corrected

0 = False (in vacuo angles ie angles if no atmosphere is assumed)

1 = True (apparent angles with refraction included)

3.6.2. Notes

Point angle records should only be written when one of the angles changes “significantly”, which means a change of at least 0.001 degrees.

Is 0.001 degrees too fine?

3.7. Calibration Record

The calibration record contains statistics of accepted calibration measurements. It may be associated with calibrations at the station or target. The file will contain as many calibration records as required, but there must be at least one station calibration record in the file at the station level. Each calibration record is applicable to the subsequent block(s) of range records.

3.7.1. Format:

A2(1-2) Record Type (= "40")

F18.12 Seconds of day (typically to < 100ns for SLR/LLR or <1 ps for transponder ranging). Station clock corrections should be applied for all targets.

I1 Type of data

0=station

1=target (e.g. transponder)

A4 System configuration id

I8 Number of data points recorded (= -1 if no information)

I8 Number of data points used (= -1 if no information)

F7.3 One way target distance (meters, nominal) (= -1 if no information)

F10.1 Calibration System Delay (picoseconds)

F8.1 Calibration Delay Shift - a measure of calibration stability (picoseconds).

F6.1 Root Mean Square (RMS) of raw system delay (ps). If pre- and post- pass calibrations are made, use the mean of the two RMS values, or the RMS of the combined data set.

F7.3 Skew of raw system delay values from the mean. If pre- and post- pass calibrations are made, use the mean of the two skew values, or the skew of the combined data set.

F7.3 Kurtosis of raw system delay values from the mean. If pre- and post- pass calibrations are made, use the mean of the two kurtosis values, or the kurtosis of the combined data set.

F6.1 System delay peak – mean value (ps)

I1 Calibration Type Indicator

0 = Not used or undefined

1 = Nominal (from once off assessment)

2 = External cals

3 = Internal cals

4 = Burst cals

5 = Other

I1 Calibration Shift Type Indicator

0 = Not used or undefined

1 = Nominal (from once off assessment)

2 = Pre – to Post- Shift

3 = Minimum to maximum

4 = Other

3.7.2. Notes

Nominal calibrations are intended for generally low accuracy systems that do not have access to high precision system delay measurements, but rather depend on fairly static and infrequent assessments of system delay. For example, use nominal calibrations for engineering data while a station is being developed, or for other special purposes.

It is expected that one calibration record is expected for a normal point data block, but this record could be used to also provide single shot measurements or indeed averaged blocks ("normal points") of internal calibrations for example.

3.8. Session (Pass) Statistics Record

The session (pass) statistics record contains averaged statistics derived from measurements taken during the session (or over the duration of a pass). The file will contain blocks of one or more range records corresponding to a consistent format. One session statistics record should be associated with each of these data blocks.

3.8.1. Format:

A2(1-2) Record Type (= "50")

A4 System configuration id.

F6.1 Session RMS from the mean of raw, accepted range values minus the trend function (ps).

F7.3 Session Skewness from the mean of raw accepted range values minus the trend function.

F7.3 Session Kurtosis from the mean of raw accepted range values minus the trend function.

F6.1 Session peak – mean value (ps)

I1 Data quality assessment indicator. For SLR and LLR data:

0 = Undefined or no comment.

1 = Clear, easily filtered data, with little or no noise.

2 = Clear data with some noise; filtering is slightly compromised by noise level.

3 = Clear data with a significant amount of noise, or weak data with little noise. Data are certainly present, but filtering is difficult.

4 = Un-clear data; data appear marginally to be present, but are very difficult to separate from noise during filtering. Signal to noise ratio can be less than 1:1.

5 = No data apparent.

3.8.2. Notes

This record is only required in combination with a number of normal point records. It is optional with full rate or engineering data records.

3.9. Compatibility Record

This record is provided primarily to allow reformatting of old data from the ILRS normal point and full-rate data to this format, without losing existing data.

3.9.1. Format:

A2(1-2)	Record Type (= "60").
A4	System configuration id.
I1	System CHange indicator (SCH)
	A flag to increment for every major change to the system (hardware or software). After the value '9' return to '0', and then continue incrementing. The station and data centers should keep a log in a standard format of the value used, the date of the change, and a description of the change.
I1	System Configuration Indicator (SCI)
	A flag used to indicate alternative modes of operation for a system (e.g., choice of alternative timers or detectors, or use of a different mode of operation for high satellites). Each value of the flag indicates a particular configuration, which is described in a log file held at the station and at the data centers. If only a single configuration is used then use a fixed value. If a new configuration is introduced then use the next higher flag value. If value exceeds '9' then return to '0', overwriting a previous configuration flag (it is not likely that a station will have 10 current possible configurations).

3.9.2. Notes

None

3.10. User Defined Record

This record is provided to allow special interest users or groups to add non-standard data records. Other uses must be able to ignore such records (if they exist in a file) without any impact. Record types outside this range will be reserved for future standard format use.

3.10.1. Format:

A2(1-2)	Record Type (= "9X", X = 0…9).
3-80	User defined format

3.10.2. Notes

None

3.11. Comment Record

Comment records are optional, and allow users to insert comments or notes as deemed necessary and appropriate.

3.11.1. Format:

A2(1-2)	Record Type (= "00").
A80	Free format ASCII comments (terminated by an end-of-line character).

3.11.2. Notes

To ensure line lengths do not become excessive, a limit of 80 characters is set. Lines exceeding this limit may be truncated. Multiple comment lines are encouraged. Comment lines can occur anywhere within a file.

4. Record Structure

The records as defined should have the potential for storing a quite complex mix of data types while maintaining data integrity. The format must support a consistent, unambiguous data set that can be readily parsed for currently used and expected data sets, and for data sets that are possible in the future. The data stored in a CRD file should be capable of being stored in a normalized database and/or expressed in the XML language. The definitions of the records have kept this in mind.

It is important that, unless totally unavoidable, data fields are not repeated as this has the potential for undermining the requirement for unambiguous and consistent data. It is also efficient in terms of file sizing and storage.

Consider a number of cases. The first is simple case where the station is performing basic satellite tracking and is creating full rate and normal point files. In practice, this will probably represent the majority of files most of the time, at least for the present.

A more complex case where a station is performing two-colour ranging and wants to store both full rate and normal point data in the one file, or when a site is publishing full rate data from experiments in time transfer using target transponders.

4.1. Case 1

Two files containing full rate for one target and normal point data for one period (for example, one day). This is typical for existing normal point (.qld) and fullrate (.fr) files being generated at many stations. (Comment records are not considered here.)

Full rate file for 1 target, single system configuration.

Format Header

Station Header

Target Header

Laser Configuration Record

Detector Configuration Record

Timing System Configuration Record

System Configuration Record

Calibration Record

    Session Header

        Calibration Record (if required)

        Pointing Record / Mets Record

        Data Record (Full rate) (repeated)

        Calibration Record / Pointing Record / Mets Record (as required)

        Data Record (Full rate) (repeated)

        Calibration Record (if required)

Pointing Record / Mets Record

End Of Session Header

Session Header

Calibration Record (if required)

Pointing Record / Mets Record

Data Record (Full rate) (repeated)

Calibration Record / Pointing Record / Mets Record (as required)

Data Record (Full rate) (repeated)

Calibration Record (if required)

Pointing Record / Mets Record

End of session Header

…… (as many session as required)

End of file header

Normal point file for many targets, single system configuration.

Format Header

Station Header

Laser Configuration Record

Detector Configuration Record

Timing System Configuration Record

System Configuration Record

Calibration Record

Target Header

Session Header

Calibration Record (if required)

Mets Record

Data record (normal point) (repeated)

Mets Record

Data record (normal point) (repeated)

Mets Record

Pass Record

End of session header

….. other sessions for this target as required

Target Header

…. Repeat as above for as many targets as required

End of session header

End of file header

This would correspond to files having a record sequence such as

H1 H2 C0 C1 C2 C3 40 H3 H4 20 30 40 10 10 10...20 10 10...30 10 10...40...10 10 20 H8 H4 20 30 40 10 10 10...20 10 10...30 10 10...40...10 10 20 H8 H4...H8...H9

and

H1 H2 C0 C1 C2 C3 40 H3 H4 40 20 11 11 11...20 11 11...20.12 H8 H4 40 20 11 11 11...20 12 H8 H3 H4 40 20 11 11 11...20 11 11...20 12 H8 H4 40 20 11 11 11...20 12 H8...H8...H9

4.2. Case 2

One file containing full rate and normal point data for one target for one period (for example, one day) from a station performing two-colour ranging (or any other dual configuration) ranging.

Full rate and normal point file for 1 target, two system configurations.

Format Header

Station Header

Target Header

Laser Configuration L1 Record

Laser Configuration L2 Record

Detector Configuration D1 Record

Detector Configuration D2 Record

Timing System Configuration (TS) Record

System Configuration S1 Record (L1-D1-TS)

System Configuration S2 Record (L2-D2-TS), or whatever is appropriate

Calibration (system S1) Record C1

Calibration (system S2) Record C2, or whatever is appropriate.

Session Header (full rate)

Calibration Records C1 and/pr C2 (if required)

Pointing Record / Mets Record

Data Record for S1 (Full rate) (repeated)

Data Record for S2 (Full rate) (repeated)

Calibration Records / Pointing Record / Mets Record (as required)

Data Records for S1 (Full rate) (repeated)

Data Records for S2 (Full rate) (repeated)

Calibration Records (if required)

Pointing Record / Mets Record

End of session Header

Session Header (normal point)

Mets Record

Data Record for S1 and/or S2(normal point) (repeated)

Mets Record

Data Record for S1 and/or S2 (normal point) (repeated)

Mets Record

End of session Header

Session Header (full rate)

…. (Repeat as above for as many sessions as required)

End of session Header

End of file header

This would correspond to files having a record sequence such as

H1 H2 H3 C0 C0 C1 C1 C2 C2 C3 H4 20 30 40 40 10 10 10 10...20 10 10 10 10...30 10 10 10 10...40...10 10 20 H8 H4 20 11 11 11 11...20 11 11 11 11...11 11 11 11...11 11 20 H8 H4 20 30 40 40 10 10 10 10...20 10 10 10 10...30 10 10 10 10...40...10 10 20 H8 H4 20 11 11 11 11...20 11 11 11 11...11 11 11 11...11 11 20 H8…H8 H9.

4.3. Case 3

One file containing full rate data for one target from a station performing experiments in time transfer via a transponder in association with another station.

Full rate 1 target, two system configurations.

Format Header

Station Header

Target Header

Laser Configuration Record

Detector Configuration Record

Timing System Configuration Record

Transponder Configuration Record

System Configuration Record

Calibration Record (Site)

Calibration Record (Target)

Session Header (full rate)

Calibration Record (Site) (if required)

Calibration Record (Target) (if required)

Pointing Record / Mets Record

Data Record (Full rate, range and transmit epoch) (repeated)

Data Record (Full rate, receive epoch only) (repeated)

Pointing Record / Mets Record

End of session Header

End of file header

4.4. Case 4

In this case, several fullrate or normalpoint sessions from one station are sent in a single file from the station to a data center. There are two ways of doing this:

4.4.1. Preferred method

H1 H2 H3 H4 ... H8

H3 H4 ... H8

...

H3 H4 ... H8 H9

This ordering is more hierarchical and is more compatible with parsing into XML.

4.4.2. Acceptable, but not preferred, method

H1 H2 H3 H4 ... H8

H1 H2 H3 H4 ... H8

...

H1 H2 H3 H4 ... H8 H9

This ordering is syntactically correct, and may be easier to implement when converting data in the old format to CRD.

5. File Naming

Since the proposed data format is so flexible and a file could contain many data types and cover any number of periods, file naming becomes a real issue. Therefore there must be a number of conventions adopted. Proposed conventions are:

1. File names and file naming conventions do not form the basis for file processing except for files that have well defined and specific file extensions (such as .Z for extraction purposes).
2. File names ending in ".NPT", ".FRD", or ".QLK" contain single data types, but possibly multiple satellites and stations.
3. File names ending in ".CRD" may contain multiple data types.
4. Files are delivered to specific file repositories in which it has been agreed and understood that certain file operations will be performed. Hence the onus is on the supplier to provide the appropriate type of file to the repository.
5. Published files will always have a unique file name. (Pertains to station naming conventions.)
6. Release versions are maintained within the data file headers. Data center files names will not include release information.
7. File processing will require files to be opened and parsed to determine what operations, if any, are to be performed.

5.1. Station Naming Convention

This naming convention is for use with files transmitted from the station to the data***THIS CONVENTION IS UNDERGOING REVISION***

date[_station-name][_target-name][_mjd][_type][_other].crd

where the [] indicates optional fields and

- Date is the date and time of production/transmission in format yyyymmddhhmmss.
- Station-name is the station name with no white spaces, if the file contains only data from that station,
- Target-name is the target name with no white spaces, if the file contains only data for that target,
- Mjd is the integral modified julian date if the file contains data for that one day only,
- Type is one of the following if the file contains only data of that type,

    "np" for normal point data,

    "fr" for full rate data, and

    "ql" for engineering, quick look data.

- Other is a suitable string without white spaces, if none of these options are appropriate.

Files may contain the ".Z", ".z", or ".zip" extension indicating a particular type of file compression.

5.2. Data Center Naming Convention

Data centers (e.g. CDDIS and EDC) will use these file names at their ftp and web sites. These are the file names the users will see when retrieving data for their analysis work. Each file will contain only one type of data.

satname_yyyymmddhh.typ (hourly)
satname_yyyymmdd.typ (daily)
satname_yyyymm.typ (monthly)
satname_yyyy.typ

where

- satname is from a standard ILRS list of spacecrafts;
- yyyy is the 4-digit year,
- mm is the 2-digit month,
- dd is the 2-digit day,
- hh is the 2-digit hour, and
- typ is
    - frd – full-rate data,
    - qlk – engineering sampled engineering data,
    - npt – normal point data.

Examples: starlette_2006091011.frd
lro_200810.npt

Files may contain the ".Z" or ".z" extension indicating file compression.

5.3.

6. Sample Files

This section includes passes and samples of passes represented in the CRD format. Note that record lengths were kept short by using “%.*x*f” c language formats for most floating point fields.

6.1. Fullrate

Filename: lageos2_7080_crd_20061113152300_01.frd

```
H1 CRD  1 2007  3 20 14
H2 MLRS       7080 24 19 4
H3 LAGEOS2     9207002 5986    22195 0
H4  0 2006 11 13 15 23 52 2006 11 13 15 45 35  1 1 1 1 0 0 2
C0 0 532.000 std1
60 std1 5 2
10 55432.0414338     0.047960587856 std1 2 0 0 0
12 55432.0414338 std1 20735.0 1601.0000 0.00 0.0000
20 55432.0414338  801.80  28.21   39
30 55432.0414338 297.2990  38.6340 0 2 1
40 55432.0414338 0 std1       -1       -1 0.000 -913.0 0.0 56.0 -1.000 -1.000 -1.0 3 3
10 55435.6429746     0.047926839980 std1 2 0 0 0
12 55435.6429746 std1 20697.0 1601.0000 0.00 0.0000
30 55435.6429746 297.4480  38.7190 0 2 1
...
10 56735.8021609     0.046094881873 std1 2 0 0 0
12 56735.8021609 std1 18092.0 1601.0000 0.00 0.0000
30 56735.8021609  15.2330  45.7100 0 2 1
H8
H9
```

6.2. Normal Point

File name: lageos2_7080_crd_20061113152300_01.npt

```
H1 CRD  1 2007  3 20 14
H2 MLRS       7080 24 19 4
H3 LAGEOS2     9207002 5986    22195 0
H4  1 2006 11 13 15 25  4 2006 11 13 15 44 40  0 0 0 0 1 0 2

C0 0 532.000 std1
60 std1 5 2
11 55504.9728030 0.047379676080 std1 2  120     18      94.0 -1.000 -1.000 -1.0 0.0
20 55504.9728030  801.80 282.10   39
```

```
40 55504.9728030 0 std1       -1       -1 0.000 -913.0 0.0 56.0 -1.000 -1.000 -1.0 3 3
11 55988.9809589 0.044893190432 std1 2  120     19      83.0 -1.000 -1.000 -1.0 0.0
20 55988.9809589  801.50 282.80   39
11 56141.8467215 0.044635017248 std1 2  120     28      66.0 -1.000 -1.000 -1.0 0.0
11 56223.2817254 0.044605221903 std1 2  120     25      87.0 -1.000 -1.000 -1.0 0.0
20 56223.2817254  801.50 282.60   39
11 56373.5463612 0.044746486398 std1 2  120     25      78.0 -1.000 -1.000 -1.0 0.0
20 56373.5463612  801.50 282.10   39
11 56439.9749454 0.044889147842 std1 2  120     25      99.0 -1.000 -1.000 -1.0 0.0
11 56565.2288146 0.045288773098 std1 2  120     25      92.0 -1.000 -1.000 -1.0 0.0
11 56680.8785419 0.045804632570 std1 2  120     10      55.0 -1.000 -1.000 -1.0 0.0
20 56680.8785419  801.50 282.00   39
50 std1 86.0 -1.000 -1.000 -1.0 0
H8
H9
```

6.3. *Sample Engineering (Quicklook)*

File name: lageos2_7080_crd_20061113152300_01.qlk

```
H1 CRD  1 2007  3 20 14
H2 MLRS       7080 24 19 4
H3 LAGEOS2     9207002 5986    22195 0
H4  2 2006 11 13 15 24 17 2006 11 13 15 44 59  0 0 0 0 0 0 2
C0 0 532.000 std1
60 std1 5 2
10 55457.0521861     0.047753624332 std1 2 0 0 0
20 55457.0521861  801.80 282.10   39
30 55457.0521861 298.3470  39.2230 0 0 0
10 55482.4631214     0.047552685849 std1 2 0 0 0
30 55482.4631214 299.4370  39.8100 0 0 0
...
10 56589.0390552     0.045383653062 std1 2 0 0 0
20 56589.0390552  801.50 282.00   39
30 56589.0390552   6.7380  47.9120 0 0 0
10 56623.4538362     0.045531247776 std1 2 0 0 0
```

```
30 56623.4538362   8.8120  47.4510 0 0 0
10 56657.6685552     0.045690091816 std1 2 0 0 0
30 56657.6685552  10.8230  46.9570 0 0 0
10 56699.7866762     0.045901952309 std1 2 0 0 0
30 56699.7866762  13.2310  46.3060 0 0 0
50 std1 86.0 -1.000 -1.000 -1.0 0
H8
H9
```

6.4. Sample 2-Color Normal Point file

File Name: lageos1_7810_crd_20061230073543_01.npt

```
H1 CRD  1 2007  3 20 14
H2 ZIMMERWALD 7810 68  1 7
H3 LAGEOS1     7603901 1155     8820 0
H4  1 2006 12 30  7 35 34 2006 12 30  8 12 29  0 0 0 0 1 0 2
C0 0 846.000 std1
C0 0 423.000 std2
60 std1 9 0
60 std2 9 1
11 27334.1080890 0.051571851861 std1 2  120     36     154.0 -1.000 -1.000 -1.0 0.0
20 27334.1080890  923.30 275.40   43
40 27334.1080890 0 std1       -1       -1 0.000 113069.0 0.0 138.0 -1.000 -1.000 -1.0 2 2
11 27343.5080895 0.051405458691 std2 2  120     28      79.0 -1.000 -1.000 -1.0 0.0
11 27372.6080888 0.050895050517 std2 2  120     30      76.0 -1.000 -1.000 -1.0 0.0
11 27373.1080893 0.050886342010 std1 2  120     17     158.0 -1.000 -1.000 -1.0 0.0
11 28003.8080894 0.042252027043 std1 2  120     19     170.0 -1.000 -1.000 -1.0 0.0
20 28003.8080894  923.40 275.50   42
11 28008.7080899 0.042208378233 std2 2  120     85      71.0 -1.000 -1.000 -1.0 0.0
11 28402.1080897 0.040251470202 std1 2  120      6     183.0 -1.000 -1.000 -1.0 0.0
11 28406.5080897 0.040247878310 std2 2  120     45      78.0 -1.000 -1.000 -1.0 0.0
11 28620.0080896 0.040574433849 std1 2  120     18     163.0 -1.000 -1.000 -1.0 0.0
20 28620.0080896  923.50 275.50   42
```

11 28627.6080899 0.040603966534 std2 2 120 114 71.0 -1.000 -1.000 -1.0 0.0

11 29151.2080895 0.045287136931 std2 2 120 7 65.0 -1.000 -1.000 -1.0 0.0

11 29156.7080892 0.045360524908 std1 2 120 7 134.0 -1.000 -1.000 -1.0 0.0

20 29156.7080892 923.50 275.80 42

11 29225.6080889 0.046314735294 std1 2 120 45 164.0 -1.000 -1.000 -1.0 0.0

11 29237.7080892 0.046488750878 std2 2 120 50 78.0 -1.000 -1.000 -1.0 0.0

11 29326.8080894 0.047825380133 std1 2 120 49 152.0 -1.000 -1.000 -1.0 0.0

11 29334.2080895 0.047940570614 std2 2 120 73 85.0 -1.000 -1.000 -1.0 0.0

11 29461.4080892 0.050011219353 std2 2 120 29 76.0 -1.000 -1.000 -1.0 0.0

11 29477.2080896 0.050279566397 std1 2 120 25 187.0 -1.000 -1.000 -1.0 0.0

11 29544.4080897 0.051445695153 std1 2 120 19 164.0 -1.000 -1.000 -1.0 0.0 11 29549.5080897 0.051535764981 std2 2 120 14 87.0 -1.000 -1.000 -1.0 0.0

50 std1 165.0 -1.000 -1.000 -1.0 0

50 std2 78.0 -1.000 -1.000 -1.0 0

H8

H9

6.5. Sample Configuration Segment

The previous examples were converted from existing data files. For new data where configuration information is available while forming the CDR, the following could replace the C0 and 60 records for MLRS tracking a lunar transponder. (The values are not necessarily realistic.)

C0 0 532.0 std1 slrd las1 tim1 lro

C1 0 las1 Nd-Yag 1064.0 10.0 100 200 20 1

C2 0 slrd MCP 532.0 8 1300 1 TTL 10 1.0 50 10 none

C3 0 tim1 TAC na MLRS na 0

C4 0 lro 100 5 325 8 12345678m1 0 1

7. Resources

The official list of satellite names and numerical identifiers can be found at:

http://ilrs.gsfc.nasa.gov/products_formats_procedures/satellite_names.html .
The satellite numerical identifiers can be found at:

http://ilrs.gsfc.nasa.gov/satellite_missions/list_of_satellites/index.html .

The official list of station names can be found at:

TBD .

The official list of station monument (pad) numbers and codes can be found at:

http://ilrs.gsfc.nasa.gov/stations/sitelist/index.html .

Find information on site files at:

http://ilrs.gsfc.nasa.gov/stations/site_procedures/site_logs/site_log_procedure.html .

Find formats for the pre-CRD data formats at:

http://ilrs.gsfc.nasa.gov/products_formats_procedures/normal_point/np_format.html

and

http://ilrs.gsfc.nasa.gov/products_formats_procedures/fullrate/fr_format_v3.html .

The latest official version of this document can be found at:

http://ilrs.gsfc.nasa.gov/products_formats_procedures/crd.html .

8. Common Abbreviations

CRD	Consolidated laser Ranging Data Format
COSPAR	Committee on Space Research, a Committee of ICSU, the International Council for Science.
CPF	Consolidated laser ranging Prediction Format
ILRS	International Laser Ranging Service
LLR	Lunar Laser Ranging
LRO	Lunar Reconnaissance Orbiter
ND	Neutral Density, which describes opacity of a broad band optical filter.
NORAD	The North American Aerospace Defense Command
ns	nanoseconds
ps	picoseconds
RMS	Root Mean Square. Same as standard deviation.
SLR	Satellite Laser Ranging
SCH	Station Change Indicator
SCI	Station Configuration Indicator
SIC	Satellite Identification Code, a 4 digit satellite descriptor.
SRP	System Reference Point, usually described as the first non-moving point in the telescope light path.
UTC	Coordinated Universal Time, formerly known as Greenwich Mean Time (GMT).
XML	eXtensible Markup Language.