Consolidated Laser Prediction and Data Formats: Supporting New Technology

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Abstract

The new tabular ILRS Consolidated Prediction Format (CPF) was developed to provide a single format to encompass traditional artificial satellite and lunar ranging targets as well as proposed transponder targets on or around the moon and other planets. As implementation of this format nears completion, the need to effectively handle kilohertz firing rates and transponder data in a new data format has emerged. The proposed Consolidated Laser Ranging Data Format (CRD) carries with it the lessons learned from the CPF: modularity, flexibility, and expandability.

Introduction

At the International Laser Ranging Service (ILRS) Workshop in Matera, Italy in 2000, it was decided that a new prediction format was needed to encompass the existing satellite and lunar ranging targets as well as the often-discussed transponders. In addition, there was a need to improve the predictions for low earth satellites. Thus the consolidated prediction format (CPF) was developed as a single format for all laser ranging targets, present and future. As the process of implementing the CPF is winding down, technological changes, in particular kilohertz repetition rate lasers and the Lunar Reconnaissance Orbiter (LRO) transponder are demanding that the current laser data formats be similarly reformulated. The process of creating the Consolidated Laser Ranging Data Format (CRD) is moving forward to meet LRO mission deadlines.

Consolidated Prediction Format

As described in early documents (Ricklefs, 2004, 2006), the CPF provides a method of ranging to different types of targets using one format. It therefore allows cross-technique ranging attempts, provided that a ranging station has needed hardware capabilities – such as event timers for lunar ranging.

The CPF does not rely on the on-site gravity model, tuning, separate Earth Orientation series, or drag and time bias functions that were required for the older tuned inter-range-vector (TIV) system. Instead, the new format contains untuned state vectors at appropriate intervals, typically in the ITRF system. This so-called format change is actually a change to the entire prediction scheme at the laser station from one of integration to one of interpolation.

Consolidated Prediction Format: Implementation Status

Currently (as of late October, 2006), the CPF is used exclusively in at least 22 out of the 37 ILRS Satellite Laser Ranging (SLR) stations, with one station in late stages of testing and 5 others close behind. Many of the remaining stations are not currently operational. It is expected that all operational stations will be converted by early 2007. In addition, the format is used at the one currently operating Lunar Laser Ranging (LLR) station (McDonald Laser Ranging Station), with other stations experimenting with the format. The author is also working with the LRO project to generate CPF files. This effort may result in some additional transponder-specific changes to the format.

The results from using the CPF seem to be quite promising. According to one station (Gibbs, 2006), SLR predictions are seen to be much more accurate, with 90% of passes being within +-20nsec and 99% being within +-100nsec of the predicted range.

Consolidated Laser Ranging Data Format: Motivation

The first concern with the existing data formats (ILRS, 1999, 2004) is that transponder data will not fit. Specifically, transponders will often need to deal with one-way ranges. For instance, LRO data will consist of a fire time on the ground and receive time at the satellite. This being the case, there is a need for more accuracy in the fire and receive times, as the difference between the two must accommodate the accuracy expected from a range, usually at the picosecond level. This highlights the third issue, that of clock information. The current time standards, such as GPS are accurate only to about 100ns. Thus, there must be a way of describing the time standard used to record the data – on both the ground station and spacecraft. This is accomplished with a time system flag, a time offset, and a drift rate for both. Calibration is yet another area needing expansion. In the same way that there are laser station system delays, there are similar system delays on the spacecraft that must be accounted for.

In addition to the demand to reshape the data formats for transponders, stations with kilohertz laser firing rates are becoming more common and must be accommodated. Among the advantages, kilohertz laser ranging offers the possibility to study a satellite's signature in more detail than ever before, providing details of the spacecraft rotation rate and corner cube performance (Arnold, et. al., 2004). The existing fullrate data format is cumbersome for use with high-repetition-rate systems, because there is so much redundant information found in each data record. Estimates for the draft version of the format show that fullrate file size should drop by 55-65% at 500 returns/sec and 25-30% at <10 returns/sec.

Consolidated Laser Ranging Data Format: Overview

The intent of the new format is to encompass full rate, sampled engineering, and normal point data in one flexible, ASCII data format. The structure will be similar to that for the Consolidate Prediction Format in that there are several types of header and data records, assembled in a building-block approach, with records capable of specifying data for a particular data type or spacecraft configuration. This makes the format extensible and flexible. An additional section, for system configuration information, is being considered. A configuration section would make the data more self-documenting with more detailed data being available to the analyst. As with the CPF, header records are fixed format, but data (and configuration) records are free format, allowing field sizes to be optimized for each satellite.

Sampled engineering, fullrate, and normal point data could be placed in one file or broken into 3 files. Multiple color data could be included in one file, as could data from one or more satellites or stations. Simple utility programs could facilitate the merging or parsing of files. The hope is to make the format XML-friendly so that the data files could be easily parsed and written into XML files, and an XML representation of the data could easily be written in the CRD format.

In the case of transponders, much of the data required to write the complete CRD file is not available at the ranging stations in real time. The data that is recorded can be transmitted to the mission data center where all the data is collated, quality controlled, and finally submitted to the ILRS data center. Normally, one would expect that the stations would create and submit partially populated CRD files which the mission data center would complete.

Timetable

The LRO mission has become a driver for creation and implementation of the new data format, since its schedule is so tight, with launch in late 2008. At some point a version of the format will need to be frozen for this mission, even if the format is not ready for network-wide implementation. (Fortunately, on-station data for LRO will be written into a compact intermediate format, so 2 versions of the CRD will not be implemented at participating stations.) The version presented here, version 0.09 will probably be used for LRO.

In the near future, the preliminary format will be made available on the ILRS web site. The general community will be invited to submit comments.When the format is finalized, its implementation will take place over a period of a year or so, with stations in most need of the new features implementing it first. These include kilohertz stations, transponders-ranging stations, and lunar stations. The lunar ranging on-station raw format has always contained data not transmitted through the ILRS formats.

There has been some concern on the part of analysts that they would find it disruptive to deal with more than one data format at a time. For this reason, the data centers will translate normal point data received in the new format into the current ILRS format until all stations are using the new format. At some time, historical data, especially normal points, will need to be translated into the new format. This may have to be phased in over a number of years, once the format has been implemented and as resources become available. This topic needs to be discussed in more depth.

Summary

The successful implementation of the new prediction format is drawing to a conclusion at the same time that new technology such as kilohertz ranging and the LRO transponder are demanding that the laser data formats be rewritten. The new data format (CRD) will encompass fullrate, sampled engineering, and normal point data for SLR, LLR, and TLR. As with the CPF, the CRD format will use a building-block approach to permit modularity, expandability and extensibility.

References

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[3] ILRS: "ILRS Fullrate Format Version 3", http://ilrs.gsfc.nasa.gov/products_formats_procedures/fullrate/fr_format_v3.html, 1999.

[4] ILRS: "ILRS Normal Point Format, Revision 2", http://ilrs.gsfc.nasa.gov/products_formats_procedures/normal_point/np_format.html, 2004.

[5] Ricklefs, R.: "Consolidated Laser Ranging Prediction Format: Field Tests", Proceeding of the Fourteenth International Workshop on Laser Ranging, San Fernando, Spain, 2004.

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Appendix A: New CRD Format Examples

The following data examples are based on the preliminary 0.09 version of the format and are included for demonstration purposes only. Changes being made to the format document will render these examples obsolete.

1. Headers

1.1 Basic header 1

H1 CRD 1 MLRS 2006 9 27 17 0 ENVISAT test file

Note station and satellite names.

1.2 Basic Header 2

H2 200901 6179 27386 2003 11 11 5 31 24 2003 11 11 5 32 2 52954 7080 24 19 1 0 6 7 2 0

Note the begin and end times and modified julian date of first data record as well as numerical station and satellite IDs.

1.3 Laser color record

H4 1 532.0

One such record is included for each laser color recorded in the file.

1.4 Pass Information

H5 1 -650 0 82 82

This record contains statistical information on the data and calibrations. The final format is likely to include the often-requested skew and kurtosis of the data in addition to the RMS.

1.4 End of Header

H9

Additional headers for transponders and full rate information are not shown here. Headers are fixed format

2. Data records

2.1 Range Record

10 1 2 19880.8466929 1 2 0.010936014472 0

The first long field is the transmit time, and the second long field is either range or receive time at the spacecraft. In the case of a down-link transponder, the first log field would be the transmit time at the satellite, and the second would be the receive time at the ground station. Interpretation of these fields is controlled by flags fields.

2.2 Meteorological record

20 19880.8466929 802.50 288.10 69

This record is written at the beginning of the file and thereafter only when one of the fields change “significantly”. This could be defined as twice the least significant bit of the sensor or an amount based on the field, such as 0.02mB for atmospheric pressure.

2.3 Point angles

30 19880.8466929 1 281.1890 22.4030

Point angles would be written for sampled engineering and fullrate data. After the beginning of the data, additional record are written only when a field changes “significantly.”

2.4 Corrections

40 19880.8466929 1 2 0 0 -650 0

This record includes refraction, center of mass, and system delays. Additional records are written only when a field changes “significantly.”

2.5 Range (with normal point fields)

10 2 2 19884.7472085 1 2 0.010985288919 0 15 37 73 0.0

Note that data records are written in free format.