Lunar Reconnaissance Orbiter
Radio Science
Archive Volume Software Interface Specification

version 1.1

April 19, 2011

SIGNATURE PAGE

Prepared by:

_____ _____
Gregory A. Neumann Date
LOLA Instrument co-Investigator
GSFC Code 698

Reviewed by:

_____ _____
David E. Smith Date
Principal Investigator, LOLA Instrument
GSFC Code 690.5

Approved by:

_____ _____
Stan Scott Date
LRO Project Science Data Manager
GSFC Code 451

Concurred by:

_____ _____
Susan Slavney Date
PDS Geosciences Discipline Node

_____ _____
Richard Simpson Date
PDS Radio Science Advisor

CHANGE LOG

DATE	SECTIONS CHANGED	REASON FOR CHANGE	REVISION
12/1/2010			New Issue
04/19/11	Various	Revision, PDS review	1.1

TBD ITEMS

SECTION	DESCRIPTION	RESPONSIBILITY

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

AOS	Acquisition of Signal
ASCII	American Standard Code for Information Interchange
CDDIS	Crustal Dynamics Data Information System
CRD	Consolidated Laser Ranging Data Format
DSN	Deep Space Network
FDF	Flight Dynamics Facility
FEI	File Exchange Interface
GSFC	Goddard Space Flight Center
HGA	High Gain Antenna
ICD	Interface Control Document
ILRS	International Laser Ranging Service
JPL	Jet Propulsion Laboratory
KU1S, KU2S	Kiruna, Sweden stations 1 and 2
LOLA	Lunar Orbiter Laser Altimeter
LR	Laser Ranging
LRO	Lunar Reconnaissance Orbiter
LSUTDF	Low Speed UTDF
MOC	Mission Operations Center
NAIF	Navigation and Ancillary Information Facility
NASA	National Aeronautics and Space Administration
NGSLR	Next Generation Satellite Laser Ranging
PAD	Pad on which receiver is installed
PDS	Planetary Data System
POD	Precision Orbit Determination
RDA	Raw Data Archive
RGS	Remote Ground Station
RS	Radio Science
SCN	Space Communications Network
SDO	Solar Dynamics Observatory
SFF	Small Forces File
SIS	Software Interface Specification
SOC	Science Operations Center
SPK	Spacecraft and Planetary Kernel

TBD	To Be Determined
TRK	Tracking Data Format file
USN	Universal Space Network
UTDF	Universal Tracking Data Format
WEA	Station Weather Data file
WS1, WS2	Stations 1 and 2 at White Sands
WU1S, WU2S	Stations 1 and 2 at Weilheim, Germany

GLOSSARY

Archive – An archive consists of one or more data sets along with all the documentation and ancillary information needed to understand and use the data. An archive is a logical construct independent of the medium on which it is stored.

Archive Volume, Archive Volume Set – A volume is a unit of media on which data products are stored; for example, one DVD-ROM. An *archive volume* is a volume containing all or part of an archive; that is, data products plus documentation and ancillary files. When an archive spans multiple volumes, it is called an *archive volume set*. Usually the documentation and some ancillary files are repeated on each volume of the set so that a single volume can be used alone. A 'logical volume' is a conceptual volume — the data products plus documentation and ancillary files — that would ordinarily be stored on a unit of media, but without the media. Archives stored on large magnetic disks are sometimes described as being on single logical (electronic) volumes.

Catalog Information – Descriptive information about a data set (e.g. mission description, spacecraft description, instrument description), expressed in Object Description Language (ODL) suitable for loading into a PDS catalog.

Data Product – A labeled grouping of data resulting from a scientific observation, usually stored in a pair of files. The label file identifies, describes, and defines the structure of the data file. An example of a data product is a planetary image, a spectrum table, or a time-series table plus its label file.

Data Set – An accumulation of data products. A data set together with supporting documentation and ancillary files is an archive.

GEODYN – An orbital and geodetic parameter estimation program that estimates a set of orbital elements, station positions, measurement biases, and force model parameters such that the orbital tracking data from multiple arcs of multiple satellites best fits the entire set of estimation parameters.

SPICE – An information system maintained by the PDS NAIF Node to assist scientists in planning and interpreting scientific observations from space-based instruments.

Standard Data Product – A data product generated in a predefined way using well-understood procedures, processed in "pipeline" fashion. (Data products that are generated in a nonstandard way are sometimes called *special data products*.)

1. INTRODUCTION

1.1 Purpose and Scope

This Software Interface Specification (SIS) describes the format and content of the Lunar Reconnaissance Orbiter (LRO) Radio Science (RS) Raw Data Archive (RDA). The LRO RS RDA represents the complete archive of raw data from investigations conducted using the radio and laser links between the LRO spacecraft and its tracking stations. The archive is generated by the Lunar Orbiter Laser Altimeter (LOLA) Science Operations Center (SOC). It is maintained and distributed by the Planetary Data System (PDS).

The communication, tracking, and timekeeping systems on LRO support generation of the precise geo-location needed by the LRO science and measurement investigations. The information provided by these systems is similar to conventional Radio Science data, although traditional 'radio science' was not an initial mission objective. The importance of the tracking data for all of the other LRO investigations merits its being archived for completeness and future analysis.

This SIS is intended to provide enough information to enable users to understand the format and content of the Archive. Typically, these individuals would be software engineers, data analysts, or planetary scientists.

The specifications in this document apply to all RS RDA volumes that are generated by the LOLA Science Team.

1.2 Data Overview

The LRO RS RDA contains data collected at a number of locations that track and communicate with the spacecraft.

LRO is tracked via a network of Earth ground stations called the Space Communication Network (SCN). The SCN consists of the NASA Deep Space Network (DSN), a new dedicated 18-m S-band antenna at White Sands (New Mexico), a network of Universal Space Network (USN) S-band tracking stations, and the Next Generation Satellite Laser Ranging (NGSLR) station laser tracking station at the GSFC in Greenbelt, Maryland. The DSN was used during the LRO commissioning phase, but is not used for routine orbital operations. The primary USN stations supporting LRO are located at Dongara (Australia) and Weilheim (Germany), while backup stations are located at South Point (Hawaii), Kiruna (Sweden), and the Solar Dynamics Observatory (SDO) at White Sands. Coordinates of these stations are given in the INST.CAT file in the CATALOG directory.

LRO is tracked via the S-band network for 30 minutes of every lunar orbit. Tracking measurements consist of two-way coherent range and Doppler measurements. Radio doppler and range tracking to LRO's omnidirectional antenna and gimbaled, high-gain antenna (HGA) are the primary data source for this archive. The spacecraft Radio Frequency subsystems are described in detail in Tooley et al. (2010) [10].

LRO is tracked by the laser ranging station at GSFC whenever weather and geometry allow. The HGA carries a small, co-boresighted, optical receiver telescope. The laser range (LR) measurement consists of a one-way forward range measurement time-tagged onboard the spacecraft using an Ultra-Stable oscillator (USO). The laser range measurement is downlinked with science data. Ground processing is handled jointly by the LOLA SOC and the Crustal Dynamics Data Information System (CDDIS). Details of the LR subsystem are given in Zuber et al. (2010) [12] and in the LOLA instrument description by Smith et al. (2009) [9]. Ongoing participation by the International Laser Ranging Service (ILRS) network of stations continues to provide further LR data that are received and processed by the LOLA SOC.

Ka-band ground stations at White Sands (WS1 and WS2) collect downlinked science data but are not directly involved in LRO tracking.

1.3 Content Overview

This SIS describes the format, content and generation of the LRO RS RDA. As this is a raw data archive, there is minimal processing of the data collected. Only the Geodyn SPK files can be considered 'derived' data. No plans exist for including other high level products in this archive.

This archive is delivered to the PDS by the LRO LOLA Science Team under the data set ID LRO-L-RSS-1-TRACKING-V1.0. The data set begins with the launch of LRO in June 2009, and is ongoing throughout the mission.

The following types of data are archived:

1. TRK: Tracking Data File; sent from the LRO tracking stations to the LRO Flight Dynamics Facility (FDF). These data are then transferred via the LRO Mission Operations Center (MOC) to the LOLA SOC.
2. WEA: Weather Data from the ground stations; contain information such as temperature, pressure, wind speed and relative humidity.
3. SFF: Small Forces Files from LRO FDF, describe the cumulative effects of thruster firing over given time intervals.
4. RANGE: Laser Ranging Data; one way laser ranging fire time. Data received by the LRO MOC, and processed into normal point and full rate data by the LOLA SOC.
5. SPK: Geodyn trajectory files from the LOLA Precise Orbit Determination Team, used for geolocation of LOLA data. These binary files contain spacecraft and planetary ephemerides, and are provided as an example of a product derived from the raw data in this archive.

These data can be classified as primary or ancillary. The spacecraft tracking data (TRK) and the Laser Ranging data (RANGE) are primary. All other files provided, with the exception of SPK files, are used to analyse and interpret tracking data, and can be classified as ancillary. The SPK files are derived products but are included here as an illustration of the utility of this dataset. Further details on the data types can be found in DATASET.CAT in the CATALOG directory.

1.4 Applicable Documents and References

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11. *STDN724: Tracking and Acquisition Handbook for the Spaceflight Tracking and Data Network*, Revision 5, Space Communications Program, Goddard Space Flight Center, Greenbelt, Maryland, 1990-2006.
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The Lunar Reconnaissance Orbiter Laser Ranging Investigation, Space Science Reviews, 150, 63-80, 2010.

2. RAW DATA ARCHIVE CHARACTERISTICS AND ENVIRONMENT

2.1 Instrument Overview

The communication, tracking, and timekeeping systems on LRO support the precise geolocation needed by the LRO science and measurement investigations. The information provided by these systems is similar to Radio Science data.

For further detail on the Radio Science "instrument", please see INST.CAT, DATASET.CAT and MISSION.CAT in the CATALOG directory.

2.2 Data Product Overview

The Small Forces Files, Station Weather, and Laser Ranging Data Files are ASCII format of variable-length. Tracking Data Files and Geodyn Trajectory Files are of binary format. The following table defines the file type, estimated file size, frequency of delivery and source of files.

File	File Type	Estimated File Size	Frequency of Delivery	Source of Files
Tracking Data File	BINARY	5 Kbytes	per Station Contact	USN,WS1,WS2
Station Weather Data File	ASCII	5 Kbytes	per Station Contact	USN,WS1,WS2
Small Forces File	ASCII	5 Kbytes	bi-weekly	LRO MOC
Laser Ranging File	ASCII	150 Kbytes	Daily	LRO MOC, CDDIS, LOLA SOC
Geodyn Trajectory Files (SPK)	BINARY	30 Mbytes	Monthly	LOLA SOC

2.2.1 Data Product Descriptions

Tracking Data File:
The Tracking Data File provides the data required to support tracking of the orbiter and generation of orbit and mission products. Each ground station (WS1 and the USN stations) that supports tracking for the LRO mission will create the data in a format identified as the Universal Tracking Data Format (UTDF) [1, 11].

Weather Data File:
The Weather data are in an ASCII, space-delimited file format [11]. The file consists of multiple lines in which the first line contains start date (YYYYMMDD), Day of Year (DDD), and station identifier information and then there are 2:N repeating lines that provide the following information: time reference, temperature, pressure, relative humidity, and wind speed.

Small Forces File:
The Small Forces File (SFF) is the Updated Thruster Calibration Parameter Report (FDF-25) and the file includes updated parameters for the thruster calibration based on all available information received about past maneuvers [11]. This is an informational report that provides the Post-Maneuver Calibration. It provides the final assessment of how well the maneuver was executed and it uses best pre-maneuver and post-maneuver orbit solutions, and telemetry (pressures, duty cycles, and attitude) to determine a thrust scale factor that can be used to plan future maneuvers (as long as they use the same thruster set).

Laser Ranging File:
The Laser Ranging file contains the LOLA/SOC–processed one-way laser ranging fire times from data processing based on the telemetry that LOLA receives from the LRO MOC as part of the real-time and post-pass spacecraft and instrument housekeeping and measurement telemetry, and from station dependent fire time files retrieved from the Crustal Dynamics Data Information System (CDDIS) which contains files from the Next Generation Satellite Laser Ranging (NGSLR) and participating International Laser Ranging Service (ILRS) laser ranging sites. The Laser Ranging files are ASCII files [6].

Geodyn Trajectory Files:
The Geodyn Trajectory Files (SPK) are orbit reconstructions produced by the LOLA Precise Orbit Determination (POD) Team. They are used for geolocation of LOLA data – in the processing of LOLA EDRs to RDRs – and to further refine POD. These files give spacecraft and planetary ephemerides and are identical in (binary) format to SPK files (see below) generated by the LRO Flight Dynamics Facility (FDF) Team. There are some differences between the two types of SPKs – the FDF SPKs are each exactly a day long, and have discontinuities at the day boundary. Geodyn SPKs are cut at the maneuvers corresponding to mission sub-phase changes (approximately monthly). Within each such period they should have no discontinuities. The FDF SPKs can be found at naif.jpl.nasa.gov.

2.3 Data Processing

The SOC forms the full-rate laser ranging data by matching the station laser fire times with the LOLA received times from the instrument science data telemetry. The normal point data are generated using 5-second segments of ranging data. With the exception of the SPK files, no additional Radio Science data processing is performed.

2.4 Software

No software is provided with this archive. Relevant, useful tools for accessing SPICE data are found at the PDS node naif.jpl.nasa.gov.

2.5 File Naming Conventions

The file naming conventions used by the originating teams and repositories are preserved at the LOLA SOC, and modified only so as to meet naming requirements of the PDS. The naming convention for data files is described. The corresponding PDS label will bear the same file name as the datafile it describes, except for the file extension LBL.

Tracking Data File:

<File Qualifier>_<Spacecraft Designations>_<Receiver PADID>_<Date Information>.<Ext>; where

File Qualifier => 6 ASCII characters to identify the type of UTDF data

LSUTDF (indicates low-speed UTDF data)

Spacecraft Designations => 6 ASCII digits (SSSSVV) to identify the spacecraft

SSSS = Spacecraft ID (0059 for LRO)

VV = Vehicle ID number (01 for LRO)

Receiver PADID => 3 ASCII digits identify the receive station. Note that the PADIDs are subject to revision.

188	White Sands station
189	SDO backup station
103	USN Dongara
105	USN South Point, Hawaii
126	KU1S (or KU2S) - Kiruna, Sweden
128	WU1S (or WU2S) - Weilheim, Germany

Date Information => 13 ASCII characters, including two underscores, in the form of YYYY_DDD_HHMM to represent the date and time (UTC) when the station closed the data file;

YYYY	4 ASCII digits for year (2008 -2013)
DDD	3 ASCII digits for day of year (001 – 366)
HHMM	4 ASCII digits (24 hour time qualifier)

Ext => 3-character ASCII extension; TRK (default)

For example a White Sands generated low-speed UTDF tracking data file that was closed at 0957UTC on 25 January 2009 would be named:
LSUTDF_005901_188_2009_025_0957.TRK

Station Weather Data File:

<Station ID>_<Station AOS Contact Time>.<Ext> ; where

Station ID => 4 ASCII characters for the station ID

WS1S	White Sands

USPS USN Dongara
USHS USN Hawaii
KI3S Kiruna, Sweden
WG1S Wilheim, Germany

Station AOS time => 11 ASCII digits, plus one underscore character, in the form of YYYYDDD_HHMM, where AOS is Acquisition of Signal.

YYYY start year designator (2008 – 2013)
DDD start day of year (001 – 366)
HHMM – Hours and Minutes of AOS, UTC
HH (00 – 23)
MM (00 – 59)

Ext => 3-character ASCII extension, WEA

For example, a file name for a weather product from White Sands:
WS1S_2009040_0824.WEA

LRO Small Forces File:

<File Qualifier>_<Maneuver Type>_<Start Date>_<Stop Date>_<Version number>.<Ext>; where

File Qualifier = [5 Characters], for file designator; in this case, FDF25
Maneuver Type = [4-5 Characters] for the type of planned maneuver in the form of
MCCn Mid-course correction maneuver #n
LOIn Lunar Orbit Insertion maneuver #n
MOIn Mission Orbit Insertion maneuver #n

Note: The "n" for the MCC, LOI, MOI can have the suffix of "E" to represent that this is an engineering pre-burn to test the thrusters prior to the official maneuver

Sknna Station keeping maneuver #nn [either "A" or "B" as each station keeping maneuver will consist of 2 parts], for example SK01A, SK01B,
Start Date = [7 characters] seven ASCII digits for the start date in the form of YYYYDDD; where
YYYY 4 ASCII digits for start year
DDD 3 ASCII digits for start day of year
Stop Date = 7 ASCII digit for the stop date in the form of YYYYDDD; where
YYYY 4 ASCII digits for stop year
DDD 3 ASCII digits for stop day of year
Version number = [2 characters] Two ASCII digits for version number, ranging from 01 to 99
Ext = [3characters] TXT, indicating a text file format for the FDF file.

Example: a file name for the first version of a Small Forces File corresponding to the first Mission Orbit Insertion maneuver would be written as

FDF25_MOI1_2009015_2009016_01.TXT

LRO Laser Ranging File:

The Laser Ranging files are named using the convention <station_id>_<Date>.<Ext>
where

station_id [4 characters] is used to define the laser ranging station site, e.g. GO1L

Date YYYYMMDDHHMM ; where Date corresponds to the date and time the recording of that particular Normal Point file begins.

- YYYY 4 digit year (2009 – 2013)
- MM 2 digit month (01 – 12)
- DD 2 digit day (01 – 31)
- HH 2 digit hour, UTC (00 – 23)
- MM 2 digit minute, UTC (00 – 59)

Ext 3 characters; standard file extension for a Normal Point file: NPT

For a list of Laser Ranging stations, their coordinates, and their corresponding IDs/Codes please see the Appendix. Please note that in file naming, some stations have chosen to use the station ID (numbers) rather than Code (numbers and letters). The LOLA Science Team has preserved the original naming schemes for the data as transmitted to us.

Sample file name: an LR data file starting on January 20, 2009 at 1535 UTC in normal point mode recorded at Greenbelt NGSLR (GO1L) would be GO1L_200901201535.NPT

GEODYN Trajectory Files:

GEODYN SPK files are monthly orbit reconstructions produced by the LOLA Precise Orbit Determination Team in NAIF binary format.

File names have the form LRO_XX_NN_DATE.BSP.

XX mission phase: Commissioning (CO), Nominal Mission (NO), Science Mission (SM) or Extended Mission (EM)

NN lunar month number (starting from 01), where the month is defined by station keeping maneuvers rather than the civil calendar.

DATE the date this file was created, in the format YYYYMMDD (a proxy for version number)

Commissioning mission phase files do not have a corresponding lunar month number, and have the form LRO_XX_DATE.BSP.

2.6 Data Product Labels

PDS labels accompany all files contained on the LRO Radio Science RDA volume. The label can either be *attached* to (embedded in) the associated file, or it can be *detached* from it, in which case the label becomes a file in its own right with the same name as the associated file except for the extension LBL. Detached label files are located in the same directory as the associated file. Except for the files in the root and CATALOG directories (and some INFO.TXT files in several directories), all files have detached labels. Files that are pointed to from within a label file can be found either in the DOCUMENT or LABEL directory.

PDS labels provide descriptive information about the associated file. The PDS label is an object-oriented structure consisting of sets of "keyword=value" declarations. Although they are mostly self-descriptive, the format and values of the keywords are fully described in the PDS Data Dictionary (http://pds.nasa.gov/tools/ddlookup/data_dictionary_lookup.cfm).

3. ARCHIVE ORGANIZATION

The LRO Radio Science RDA volume consists of a root directory containing the directories CATALOG, DATA, DOCUMENT, INDEX, and LABEL. In addition, the root directory contains files pertinent to the entire volume. A description of these files and directories is provided below.

3.1 Root Directory

The root directory contains the following ASCII files:

File	Description
AAREADME.TXT	Contains a terse description of the RS archive contents and format
ERRATA.TXT	Overview of anomalies and errors; contains a cumulative listing of comments and updates concerning the archive as of the publication date
VOLDESC.CAT	Contains a description of the contents of the logical volume in a PDS format readable by both humans and computers.

3.2 CATALOG Directory

The files in the CATALOG directory provide high-level descriptions of the mission, the spacecraft, the ground system, and the data set. All are ASCII files. The files in this directory are coordinated by the PDS data engineer, who is responsible for loading them into the PDS catalog. The following files are found in the CATALOG Directory.

File	Description
CATINFO.TXT	Contains a terse description of the CATALOG directory
DATASET.CAT	Overview of the Radio Science dataset and components
INST.CAT	Description of the parties contributing to Radio Science data collection
INSTHOST.CAT	A description of the LRO spacecraft
MISSION.CAT	A description of the LRO mission and objectives
PERSON.CAT	Contact information for relevant contributors to this data set
REF.CAT	References relevant to this data archive

3.3 DATA Directory

The DATA directory contains five subdirectories corresponding to file types TRK, WEA, SFF, RANGE, and SPK. Subdirectories are created only if there are corresponding data files (there are no empty subdirectories).

Subdirectory	File Type	Description
TRK	Tracking	Tracking data files and accompanying PDS labels
WEA	Weather	Station weather files and accompanying PDS labels
SFF	Small Forces	Small forces files and accompanying PDS labels
RANGE	Laser Ranging	Laser ranging files and accompanying PDS labels
SPK	GD Trajectory	GEODYN Trajectory Files and corresponding PDS labels

3.4 DOCUMENT Directory

The DOCUMENT Directory contains documentation to help the user understand and use the archive data. The following files are contained in the DOCUMENT Directory.

File	Description
DOCINFO.TXT	Text description of the contents of the DOCUMENT directory.
LROGS_EXT_ICD (PDF, HTML,LBL)	The LRO External Systems ICD for the Ground System. It describes the WEA, SFF, and RANGE data files. In PDF, HTML formats with accompanying PDS label.
CRD_V1_01 (PDF, HTML,LBL)	A description of the standard for the Consolidated Laser Ranging Format in PDF and HTML formats with accompanying PDS label.
453_HDBK_GN (PDF, HTML,LBL)	Ground Network Tracking and Acquisition Data Handbook. It describes the TRK data file and is in HTML and PDF formats, with an accompanying PDS label.
LRORS_ARCH_SIS (PDF, HTML,LBL)	The LRO RS RDA archive volume SIS (this file), in PDF and HTML formats, with accompanying PDS label.
LRO_DESC_FDF25.TXT	This document describes the FDF-25 Thruster Calibration Data (SFF).
LRO_DESC_RANGE.TXT	A description of the Laser Ranging Data (RANGE).
LRO_DESC_TRK.TXT	A description of the Tracking Data (TRK).

3.5 INDEX Directory

The INDEX directory contains the following files:

File	Description
INDXINFO.TXT	A description of the contents of the INDEX directory
INDEX.LBL	A detached label that completely describes INDEX.TAB
INDEX.TAB	A table listing all LRO RS archive files included in this volume (RANGE, SFF, SPK, TRK, WEA)

3.6 LABEL Directory

The LABEL Directory contains files that describe data format and organization. These files are referred to in the PDS labels that accompany the data products. They are "include" files that are intended to be parsed as if they were part of the PDS labels that refer to them. The LABEL directory contains the following files:

File	Description
LABINFO.TXT	Content list for the LABEL directory
LRO_TRK.FMT	Details of the fields contained in the TRK data files.

4. RELEVANT DATA ARCHIVED AT OTHER SITES

4.1 NAIF

The Navigation and Ancillary Information Facility (NAIF) is the navigation node of the PDS. NAIF archives navigation, attitude, and some instrument data for virtually all National Aeronautics and Space Administration (NASA) missions and provides the SPICE utility software to manipulate those data. The following table contains the list of SPICE kernels that are archived at NAIF and that are useful for radio science analysis and investigations.

NAIF SPICE archive files:

Code	Description
CK-SC	spacecraft orientation
CK-HG	high gain antenna (HGA) orientation
CK-SA	solar array (SA) orientation
EK	mission event data
FK	reference frame specifications
SCLK	spacecraft clock time
SPK	planetary and satellite ephemeris data

NAIF sites useful for LRO analysis are:

Site	Contents
http://naif.jpl.nasa.gov/naif/toolkit.html	SPICE Toolkit software and documentation
ftp://naif.jpl.nasa.gov/pub/naif/generic_kernels/	Generic kernels

4.2 ILRS

The Crustal Dynamics Data Information System (CDDIS) hosts the International Laser Ranging Service (ILRS) in which satellite laser ranging data from the world wide network are archived. The normal point and full rate LR data are part of that archive. This archive will contain a subset (normal point) of that dataset.

ILRS also maintains and revises the coordinates of the laser ranging stations, which can be found at their website.

ILRS sites useful for LRO analysis are:

Site	Contents
http://ilrs.gsfc.nasa.gov/	Documentation and information on satellite laser ranging, and the ILRS
http://ilrs.gsfc.nasa.gov/products_formats_procedures/normal_point/index.html	Normal point and full rate data and info

5. SUPPORT STAFF AND COGNIZANT PERSONS

David E. Smith, LOLA Principal Investigator, NASA Goddard Space Flight Center (GSFC)

Maria T. Zuber, LOLA Deputy P.I., Massachusetts Institute of Technology

Gregory A. Neumann, LOLA co-Investigator, NASA Goddard Space Flight Center

Mark H. Torrence, LOLA Science Operations Manager, NASA Goddard Space Flight Center

Kopal Jha, LOLA Support Scientist/Data Archivist, NASA Goddard Space Flight Center

Susan Slavney, PDS Geosciences Node, Washington University, St. Louis, Missouri

Richard Simpson, PDS Radio Science Advisor, Stanford University, Stanford, California

Annette Conger, LRO RS Data Archivist, NASA GSFC Wallops Flight Facility

Appendix A: Coordinates of Data Receiving Stations

The data in this Appendix are duplicated in INST.CAT.

The USN station positions are given in the table below, in geographic coordinates (WGS-84 Ellipsoid):

Location	Station Code	Station ID	Latitude (ddmmss.ss)	Longitude (ddmmss.ss)	Altitude (m)
Kiruna	KU1S	126	67 53 22.4100	21 03 56.3571	400.4
Kiruna	KU2S	127	67 52 59.4570	21 03 37.6140	442
Weilheim	WU1S	128	47 52 48.2500	11 05 07.0890	663.39
Weilheim	WU2S	129	47 52 52.3160	11 05 01.0280	663.37
Hawaii	USHS	105	19 00 50.0562	204 20 12.1155	385.19
Dongara	USPS	103	-29 02 44.7798	115 20 55.2395	250.47

The body-fixed coordinates of the tracking stations (X, Y, Z):

Name	Code	Coordinates		
		x (km)	y (km)	z (km)
USN_Kiruna_1	KU1S	2246.85	865.44	5886.84
USN_Kiruna_2	KU2S	2247.56	865.48	5886.61
USN_Wilheim_1	WU1S	4206.09	824.08	4708.43
USN_Wilheim_2	WU2S	4206.03	823.94	4708.52
USN_Hawaii	USHS	-5496.59	-2486.04	2064.93
USN_Dongara	USPS	-2389.2	5043.29	-3078.46

The datadownlink stations are:

Name	Station Code	Coordinates		
		x (km)	y (km)	z (km)
White_Sands_Ka_band	WS1K	-1539.03	-5158.58	3411.92
SDO_backup_Ka_band	STSK	-1539.01	-5158.53	3412.01

Coordinates of the Laser Ranging stations that track the LRO HGA:

Station Name	Station Code	Station ID	Coordinates		
			x(km)	y (km)	z (km)
LR_Greenbelt_NGSLR	GO1L	7125	1130.74	-4831.37	3994.08
LR_Greenbelt_MOBLAS7	GODL	7105	1130.72	-4831.35	3994.11
LR_Hartebeesthoek_SA	HARL	7501	5085.4	2668.33	-2768.69
LR_McDonald_Texas	MDOL	7080	-1330.02	-5328.4	3236.48
LR_Monument_Peak_CA	MONL	7110	-2386.28	-4802.36	3444.88
LR_Zimmerwald_Swtzlnd	ZIML	7810	4331.28	567.55	4633.14
LR_Herstmonceaux_UK	HERL	7840	4033.46	23.66	4924.31
LR_Grasse_France	GRSM	7845	4581.69	556.2	4389.36
LR_Wettzel_Germany	WETL	7834	4075.58	931.79	4801.58
LR_Yarragadee_AU	YARL	7090	-2389.01	5043.33	-3078.53

DSN or other network stations that participated during commissioning:

Name	Station Code	Coordinates		
		x (km)	y (km)	z (km)
DSN_Goldstone_24	DS24	-2354.91	-4646.84	3669.24
DSN_Canberra_34	DS34	-4461.15	2682.44	-3674.39
DSN_Madrid_54	DS54	4849.43	-360.72	4114.62