LCROSS Project

Archive Generation, Validation and Transfer Plan

04.05.PDSArchivePlan.01.v1

April 23, 2007
LCROSS 04.05.PDSArchivePlan.01.v1

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DOCUMENT CHANGE LOG

DATE	PAGES / SECTIONS AFFECTED	REASON FOR CHANGE	VERSION/ REVISION

ITEMS TO BE DETERMINED

SECTION	TBD ITEM	RESPONSIBILITY

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FIGURES

TABLES

ACRONYMS

C&DH	Command and Data Handling
DAWG	Data and Archives Working Group
DHU	Data Handling Unit (LCROSS' Science co-processor)
EDR	Experiment Data Record
GDS	Ground Data System
GSEOS	Ground Support Equipment Operating System (the instrument ground system)
ICD	Interface Control Document
ISIS	Integrated Software for Imagers and Spectrometers
JPL	Jet Propulsion Laboratory
LCROSS	Lunar Crater Observation and Sensing Satellite
LRO	Lunar Reconnaissance Orbiter
MOC	Mission Operations Center
NAIF	Navigation and Ancillary Information Facility
NSSDC	National Space Science Data Center
PDS	Planetary Data System
RDR	Reduced Data Record
SIS	Software Interface Specification
SOC	Science Operations Center
SPICE	Spacecraft, Planet, Instrument, Pointing C-matrix, and Event kernels (historical acronym for navigation and ancillary data)
TLP	Total Luminance Photometer

1. INTRODUCTION

1.1 Purpose

The purpose of this document is to provide a plan for generation, validation, and transfer to the Planetary Data System (PDS) of archives from the LCROSS Mission. The archives will contain raw and reduced data, documentation, and algorithms or software.

1.2 Scope

The plan covers archiving of raw and reduced data sets and related information to be acquired or derived during the LCROSS mission.

Specific aspects addressed in this plan are:

- Generation of high-level mission, spacecraft and instrument documentation, instrument calibration reports, and documentation of algorithms and/or software used to produce reduced data records.
- Reduction of science packet data to reduced data records, including generation of data sets expressed in geophysical units, with associated documentation that records when and where the data were acquired and for what purpose.
- Generation of SPICE archives for use with software from the Jet Propulsion Laboratory's Navigation and Ancillary Information Facility (NAIF).
- Generation and validation of archive volumes containing LCROSS science and engineering data, software, algorithms, documentation, and ancillary information.
- Delivery to the PDS of validated LCROSS archives.

1.3 Contents

This plan begins with a summary of LCROSS mission phases and an overview of the archiving flow. This section is followed by a description of the roles and responsibilities for organizations and personnel associated with generation, validation, and archiving of LCROSS data.

1.4 Applicable Documents and Constraints

This Archive Generation, Validation, and Transfer Plan is responsive to the following documents

1. The LCROSS Project Plan (01.01.PP.01.v--)
2. The LCROSS Science Plan (04.01.SciMP.01.vDRAFT)
3. Project Requirements Document (Level 3+) Requirements Matrix (02.01.PRD.01.v--)

The plan is consistent with the principles delineated in the following National Academy of Sciences reports:

4. Data Management and Computation, Volume 1, Issues and Recommendations, 1982, National Academy Press, 167 p.
5. Issues and Recommendations Associated with Distributed Computation and Data Management Systems for the Space Sciences, 1986, National Academy Press, 111 p.

The plan is also consistent with the following Planetary Data System document:

6. Planetary Data System Standards Reference, March 20, 2006, Version 3.7, JPL D-7669, Part 2.
7. Planetary Data System Archive Preparation Guide (APG), Aug. 29, 2006, Version 1.1, JPL D-31224.

The plan requires the generation of the following Project documents:

8. Data Product Software Interface Specification (SIS) for all Standard Products.
9. Archive Software Interface Specification (SIS) for all Standard Products.
10. Interface Control Document (ICD) specifying relationships between the LCROSS Project, Science Teams, and PDS Nodes.

Finally, this plan defines how the project will implement program level requirements 3.4.1.2 and 3.4.1.3 (Project Requirements Document (Level 3+) Requirements Matrix) which state “Data products delivered to the PDS shall be documented, validated, and calibrated in physical units useable by the exploration and science communities at large” and “The time required to complete this process and make the data available to the Moon/Mars exploration communities and the general public shall be six months or less after impacting the lunar surface.”

2. LCROSS ARCHIVE GENERATION, VALIDATION, AND TRANSFER

2.1 The Mission

The **L**unar **Cr**ater **O**bservation and **S**ensing **S**atellite (LCROSS) mission is a secondary payload, sharing the Lunar Reconnaissance Orbiter (LRO) launch vehicle. LCROSS will advance the Vision for Space Exploration by investigating the presence of water ice at the Moon’s South Pole. LCROSS provides a 2000kg Kinetic Impactor that creates nearly a 1000 metric ton plume of lunar ejecta that will be visible from a number of Lunar-orbital and Earth-based assets. This impact is achieved by steering the Centaur Upper Stage of Titan IV launch vehicle into a permanently shadowed crater at the North or South Pole, resulting in a 30km plume. The LRO 1000kg Secondary Payload budget is used to provide a Shepherding Spacecraft (S-S/C) which guides the Centaur into the crater as well as creating a second impact event. Upon separation the S-S/C flies through the impact plume, telemetering real-time images and characterizing water ice in the plume with payload instrumentation consisting of Visible, Mid and Near IR cameras, a Total Luminance Photometer(TLP) and Visible and Near IR spectrometers.

Figure 2-1 shows the mission timeline, emphasizing payload operating modes. Calibration mode runs all instruments at relatively low rates to collect data to refine the calibration models. Camera mode photographs the LCROSS impactor, the Centaur upper stage, as it separates from the LCROSS Shepherding Spacecraft. Flash mode emphasizes the flash photometer and high sample rate, low resolution modes on instruments that have them. Curtain mode emphasizes

water detection and observations of the impact curtain structure. Crater mode emphasizes detecting the precise location and thermal signature of the impact.

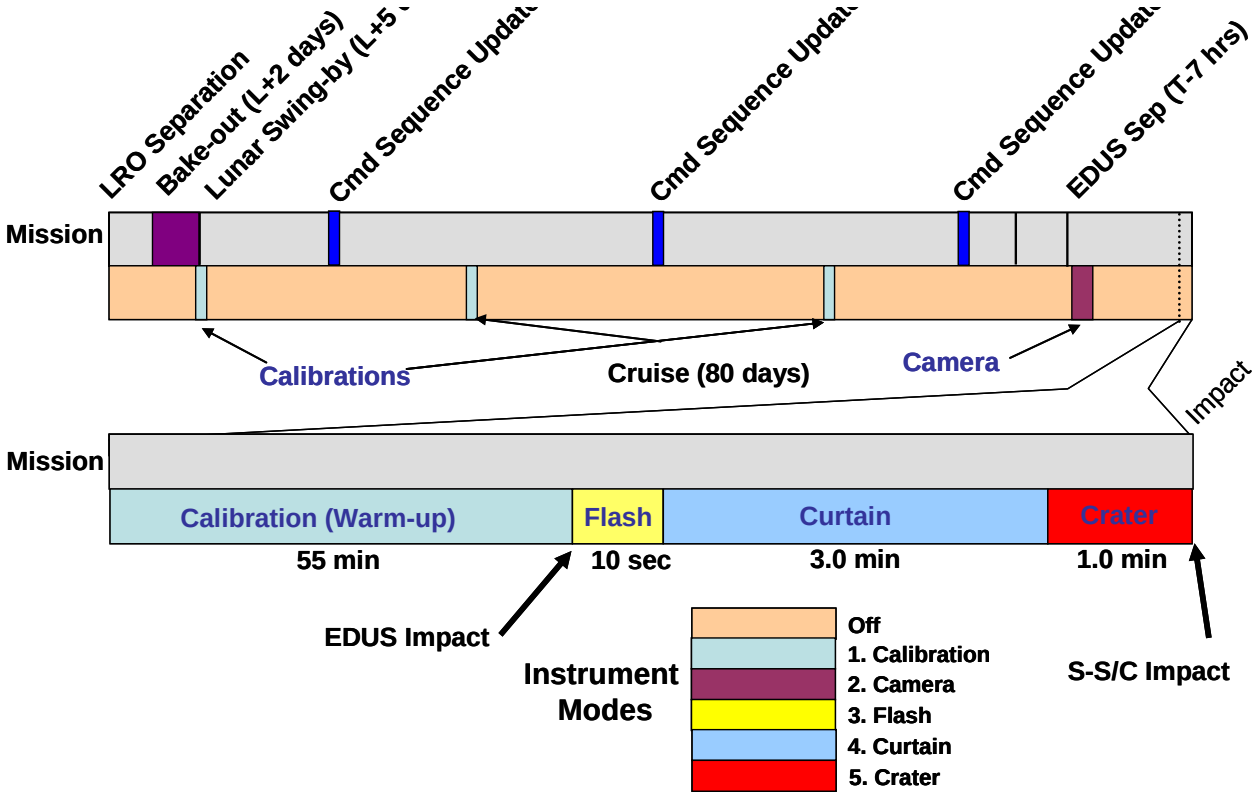


Figure 2-1 LCROSS Mission Timeline
(The launch date and cruise duration vary with different LRO launch opportunities. The baseline launch date is Oct 28, 2008.)

2.2 Data Flow

Standard data products are raw and derived products generated in "pipeline" fashion during mission operations using well-understood procedures. Each type of LCROSS standard product will be described in a Data Product Software Interface Specification (SIS) document. Science data products are listed in Table 4.

In addition to the standard products, special products may be generated by some data suppliers as time and other resources permit. Special products are generated outside the usual data processing pipeline, and are understood be completed on a best-efforts basis. Those special products that are completed and validated in time for a scheduled release to PDS may be delivered along with the standard products. PDS will continue to accept special products after the end of the mission as long as they are documented and validated according to PDS standards.

Complete archive volumes including data products, documentation, and ancillary materials are assembled by the LCROSS science team and delivered to the designated PDS Nodes. PDS personnel will work closely with science team members to ensure a smooth transfer. Table 3 lists

the elements that comprise the LCROSS archives, and Table 4 provides a detailed list of all the data sets and their producers. All archive collections will be assembled according to designs specified in Archive Volume Software Interface Specification (SIS) documents.

When data products have been delivered to the PDS, they are regarded as publicly available. It is expected that the data will be made available to the public through the PDS online distribution system. Although online access will be the primary distribution method for LCROSS archives, the PDS requires that archives be stored on appropriate physical media for long-term maintenance at the PDS and at the National Space Science Data Center (NSSDC). PDS is responsible for delivering LCROSS archives to the NSSDC.

Figure 2-2 shows how data flows from the LCROSS instruments through the Mission Operations Center (MOC) and Science Operations Center (SOC) to the PDS. Briefly, the instruments are powered and managed by the Data Handling Unit (DHU). After configuring each instrument, e.g., setting exposure times and sample rates, the DHU receives images, spectra and health status from them and timestamps and formats that data for downlink. The data passes essentially unchanged through the spacecraft Command and Data Handling system (C&DH), the Deep Space Network and the MOC. Within the SOC, GSEOS software decommutates and displays the data, including observations and health status. After payload observation periods, GSEOS will be configured to replay the data collected during that period and generate NASA Level 0 data for each instrument. This will consist of sets of uncalibrated, timestamped images and spectra. As of this writing, the process for generating Level 1 and Level 2, the box labeled "Data Analysis Tools", data has not been fully defined. However, it will include application of calibration functions to the Level 0 spectra and images, registration of the images and spectra against lunar maps using ISIS and JPL trajectory (SPICE) data products.

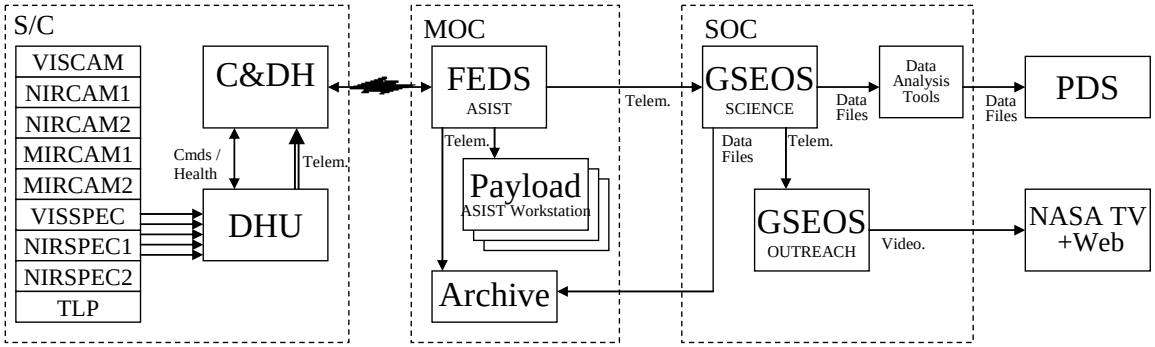


Figure 2-2 Data flow from LCROSS downlink to Planetary Data System

2.3 Data Volume

For planning purposes, the maximum expected downlinked science data volume from LCROSS is approximately 2.25 Gigabytes, corresponding to 5 hours of full rate payload telemetry. Of this, 75 Megabytes will be imagery during Centaur separation and 50 Megabytes will be during and after the Centaur impact. Level 1 and Level 2 products for the period after Centaur impact may be as much as 10 times this amount (500 Megabytes). These estimates will be refined based on further mission scenario development and data product definitions.

2.4 Data Validation and Peer Review

LCROSS science archives will be validated before being released to the PDS. Validation is accomplished in two parts: validation for scientific integrity and validation for compliance with PDS standards. Science team members are expected to conduct validation for scientific integrity in the course of their analysis of EDRs and their production of RDRs. The details of the science validation process are the responsibility of the LCROSS Principal Investigator with assistance from the instrument providers.

Validation for compliance with PDS standards is the responsibility of the payload software engineer, with help from the PDS Node that will receive the data products. PDS will provide software tools, examples, and advice to help make this part of the validation as efficient as possible. This validation includes a peer review of the design and labeling of data products as laid out in the Data Product Software Interface Specification (SIS) documents, and validation of the PDS labels using sample data. The review committee will consist of a small group of scientists who represent typical users of the data; for example, Participating Scientists, should LCROSS have any, would be good candidates for reviewers. The science team and the relevant PDS node will also be represented on the review committee. The review period will last approximately one month and will be conducted mostly by email, culminating in a teleconference if needed. The result of the review will be a list of liens, or problems, that the team must resolve before the product can pass the review. Another month (or more depending on the nature of the liens) will be allowed for the science team to address the liens. All reviews will be completed and liens resolved by six months before the start of operations. The goal is to allow the teams enough time to correct any problems before systematic generation of standard products begins. After the start of operations, when generation of products has begun, each individual product will be validated to see that it conforms to the design specified in the SIS. Validation of individual products will be automated as much as possible.

2.5 Data Delivery Schedule

The LCROSS Project Level 1 requirements state that data products shall be archived with PDS within six months of the impact. It is expected that there will be only a single delivery near the end of the six month period.

2.6 Online Access to LCROSS Archives

PDS will offer a Web-based system of access to LCROSS science data products. It will allow selection based on various search criteria, browsing of data, and downloading in various formats. The system will have capabilities designed to serve both the casual user and the expert. .

3. ROLES AND RESPONSIBILITIES

In this section the roles and responsibilities for personnel and organizations involved in LCROSS archive generation, validation, transfer, and distribution are summarized.

3.1 LCROSS Project Responsibilities

The LCROSS Project has overall responsibility for generation and validation of archives for release to the PDS. The Project is also responsible for distribution of data and associated information to LCROSS personnel.

The Principal Investigator, working with the Project Scientist, provides oversight of the archiving process. They will review data analysis plans to assure timely and adequate analysis of spacecraft data and delivery of documented, complete data to the PDS. They are responsible for the administrative management of data archive planning and implementation.

The LCROSS Data Archive Working Group (DAWG) will coordinate the planning of the generation, validation, and release of PDS-compliant archives to the PDS. The DAWG is a subgroup of the LCROSS Science Team and reports to the LCROSS Principal Investigator. The DAWG Chair is the payload software engineer who will, under the direction of the Principal Investigator and Project Scientist, ensure that archives are planned, validated, and delivered. DAWG membership includes the Principal Investigator, the Project Scientist, the payload software engineer. Representative PDS personnel will be liaison members of the DAWG. During the post mission phase, the DAWG will provide the coordination needed to ensure that archives are assembled, validated, and delivered according to schedule.

The LCROSS Science Team is responsible for generating validated, PDS-compatible archives containing EDRs and derived data products for their instruments as specified in Table 4. PDS-compatible archives include documentation, algorithms or software for generating derived data products, calibration data and reports, and other supporting materials in addition to science data products.

3.2 Planetary Data System Responsibilities

The PDS is the designated point of contact for LCROSS on archive-related issues. The PDS is also the interface between LCROSS and the National Space Science Data Center (NSSDC). The PDS will work with the DAWG to ensure that the LCROSS archives are compatible with PDS standards and formats. Personnel from the PDS Geosciences, Imaging, NAIF and Engineering Nodes will be liaison DAWG Members.

The PDS will be responsible for distribution and maintenance of LCROSS archives for the NASA planetary science community once the archives have been delivered by LCROSS.

The Geosciences Node will provide overall coordination of PDS activities for LCROSS. The Geosciences, Imaging, and NAIF Nodes will archive LCROSS data sets as designated in Table 4. A Data Engineer from the PDS Engineering Node will work with the PDS Discipline Nodes involved with LCROSS throughout the archive planning, generation, and validation phases.

3.3 National Space Science Data Center Responsibilities

The National Space Science Data Center will maintain an archive of LCROSS data for long-term preservation. The PDS will deliver at least one copy of LCROSS archive volumes to NSSDC, according to Memoranda of Understanding between the PDS and NSSDC. NSSDC may also provide support for distribution of LCROSS data to the general public, although this is beyond the domain of this Archive Generation, Validation, and Transfer Plan.

Table 1. LCROSS Payload

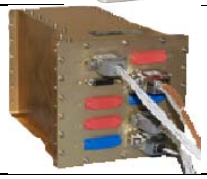
Visible Camera		Ecliptic Enterprises RocketCam	Visible context imagery; Monitor ejecta cloud morphology; Determine visible grain properties
Near Infrared Cameras		Goodrich Sensors Unlimited SU320-KTX	NIR (1.1-1.7 um) context imagery; Monitor exacta cloud morphology; Determine NIR grain properties; Water concentration maps
Mid-Infrared Cameras		Thermoteknix MIRIC TB2-30	MIR (6.5-15 um) thermal image; Monitor the exacta cloud morphology; Determine MIR grain properties; Measure thermal evolution ejecta cloud; Remnant crater imagery
Visible Spectrometer		Ocean Optics	Visible (260-660 nm) emission and reflectance spectroscopy of vapor plume, ejecta cloud; Measure grain properties; Measure emission H2O vapor disso iation, OH- (308nm) and H2O+ (609nm) fluorescence
Near Infrared Spectrometers		Polychromix	NIR (1.4-2.4 um) emission and reflectance spectroscopy of vapor plume, ejecta cloud; Measure grain properties; Measure broad H2O ice features; Occultation viewer to measure water vapor absorption by cloud particles
Total Luminance Photometer (TLP)		Ames	Measure total impact flash luminance (400-1000 nm), magnitude and decay of luminance curve
Data Handling Unit (DHU)		Ecliptic Enterprises	Instrument control and data acquisition

Table 2. Definitions of Processing Levels for Science Data Sets

NASA	CODMAC	Description
Packet data	Raw – Level 1	Telemetry data stream as received at the ground station, with science and engineering data embedded.
Level 0	Edited - Level 2	Instrument science data (e.g., raw voltages, counts) at full resolution, time ordered, with duplicates and transmission errors removed.
Level 1A	Calibrated - Level 3	NASA Level 0 (CODMAC Level 2) data that have been located in space and may have been transformed (e.g., calibrated, rearranged) in a reversible manner and packaged with needed ancillary and auxiliary data (e.g., radiances with the calibration equations applied).
Level 1B	Resampled - Level 4	Irreversibly transformed (e.g., resampled, remapped, calibrated) values of the instrument measurements (e.g., radiances, magnetic field strength).
		Resampled and mapped
Level 2	Derived - Level 5	Geophysical parameters, generally derived from NASA Level 1 data (CODMAC Levels 3 and 4) , and located in space and time commensurate with instrument location, pointing, and sampling.
Level 3	Derived - Level 5	Geophysical parameters mapped onto uniform space-time grids.
	Ancillary data – Level 6	Nonscience data needed to generate calibrated or resampled data sets. Consists of instrument gains, offsets; pointing information for scan platforms, etc. SPICE kernels are in this category.

Table 3. Components of LCROSS Archives

Component	Contents	Supplier
SPICE Archives	SPICE Kernels NAIF Software	LCROSS, NAIF
Instrument Data Archives	Experiment Data Records and Reduced Data Records	Science Teams
Supporting Materials	High-level mission, spacecraft, instrument, data set, software, and personnel descriptions for the PDS Catalog Data Product Software Interface Specification (SIS) Documents Archive Software Interface Specification Documents Processing Descriptions, Algorithms, and Software (to use in understanding reduced data product generation) Instrument Calibration Plans and Reports and associated data needed to understand level 1 product generation	Science Teams

Table 4. Standard and Special Data Products

Instrument or Data Source	Product	NASA Proces-sing Level	Standard or Special	Data Set	Producer	PDS Curator
Visible Context Camera	VCC-EDR	0	Standard	Raw image data		Img
NIR Cameras	NIR-EDR	0	Standard	Raw image data		Img
	NIR-RDR	1A	Standard	Radiometrically calibrated images		Img
	NIR-MAP	1B	**Special**	Band-depth maps		Img
Mid-IR Cameras	MIR-EDR	0	Standard	Raw image data		Img
	MIR-RDR	1A	Standard	Radiometrically calibrated images		Img
	MIR-TEMP	2	Standard	Temperature images		Img
Visible Spectrometer	VSPEC-EDR	0	Standard	Raw counts		Geo
	VSPEC-RDR	1A	Standard	Calibrated radiance		Geo
NIR Spectrometers	NSPEC-EDR	0	Standard	Raw counts		Geo
	NSPEC-RDR	1A	Standard	Calibrated radiance		Geo
	NSPEC-IOF	2	Standard	I/F		Geo
Visible Luminance Photometer	PHOTO-EDR	0	Standard	Raw counts		Geo
	PHOTO-RDR	1A	Standard	Calibrated radiance		Geo
NAIF-related data	LCROSS-LSK	N/A	Standard	Leapseconds Kernels	NAIF	NAIF
	Lunar-PCK	N/A	Standard	Planetary Constants Kernel	NAIF	NAIF

Instrument or Data Source	Product	NASA Proces-sing Level	Standard or Special	Data Set	Producer	PDS Curator
	LCROSS-SCLK	N/A	Standard	Spacecraft CLock Kernel	LCROSS	NAIF
	LCROSS-FK	N/A	Standard	Frame Specifications Kernel – includes the spacecraft and instrument boresights	LCROSS	NAIF
	Lunar-FK	N/A	Standard	An FK providing high-precision Moon frames	NAIF	NAIF
	Instrument IKs	N/A	Standard	Instrument Kernels for each instrument.	LCROSS	NAIF
	LCROSS SPKs	N/A	Standard	Spacecraft and Planet Kernels containing trajectory information pre- and post-separation	LCROSS	NAIF
	DE414	N/A	Standard	Planet/lunar ephemeris	NAIF	NAIF
	LCROSS-CKs	N/A	Standard	C-matrix Kernels containing S-S/C attitude during payload operations	LCROSS	NAIF

Geo = PDS Geosciences Node, Washington University

Img = PDS Imaging Node, JPL/USGS
NAIF = Navigation and Ancillary Information Facility, JPL

Table 5. LCROSS Archive Generation, Validation, and Release Schedule

Date	Event
October 2006	Contact initiated with PDS; DAWG meetings begin
February 2007	Mission CDR
April 2007	Final Archive Plan complete Final Interface Control Documents complete
Jan 2008	First draft of Data Product and Archive Volume SIS document(s) ready First draft of sample products with PDS labels ready Peer reviewers are identified
14 Feb 2008	Review versions of SIS(s), sample products, and labels are ready Peer Review begins
14 Apr 2008	Peer Review is complete Final versions of SISs and labels are complete
October 2008	Launch Work begins on writing PDS catalog information After "swing-by" at launch+5 days, conduct delivery tests with PDS using swing-by data products
Spring 2009	Impact event
Summer 2009	All raw and derived data products are generated by impact + 3 months
Fall 2009	All data must be delivered to PDS by impact + 6 months