Deep Impact

Project Data Management Plan

Document Number
D - 21386

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California 91109-8099

Deep Impact
Project Data Management Plan

Jointly Prepared by:

____
E. Grayzeck
University of Maryland

____
C. Acton
Jet Propulsion Laboratory

Approved by:

____
J. McKinney
Mission Operations Manager
Jet Propulsion Laboratory

____
J. Veverka
CSDC Leader
Cornell University

____
K. Meech
Team Leader for Earth-based Imaging
University of Hawaii

____
D. Yeomans
Team Leader for Radio Science
Jet Propulsion Laboratory

____
R. Benson
IPN TMS Manager for Deep Impact
Jet Propulsion Laboratory

____
L. Hall
Planetary Data System Manager
Jet Propulsion Laboratory

____
M. A’Hearn
Principal Investigator
University of Maryland

CHANGE LOG

DATE	SECTION	CHANGE
9/10/2001	All	Working draft #1 (Acton)
9/19/2001	Many	Working draft #2 (Acton)
3/15/2002	4.2, Appendix C	Working draft #3 (Acton)
6/22/2002	2.2, 5.1.1, App A	Working draft #4 (Grayzeck)
8/23/2002 5/02/2003	Many 2.1, 5.1.2b, 1.2.c	Review #1 (Acton) Update #1 (Grayzeck)
6/03/2003	Last two pages, plus misc. items elsewhere	Final (Acton)
7/2/2003	Page 10 a)	Update (Veverka)
7/7/2003	Page 4 (Table 1)	Update (Acton)
7/7/2003	Page 6 (Table 3)	Typo corrected

Reference Documents

1. Deep Impact Mission Operations Plan, JPL D-18835
2. PDS Data Preparation Workbook, JPL D-7669, Part 1
3. PDS Standards Reference, JPL D-7669, Part 2
4. The SPICE Concept, NAIF Document No. 381

ACRONYMS

ACT	Applied Coherent Technology Corporation
BATC	Ball Aerospace and Technologies Corporation
C&DH	Command and Data Handling
CCSDS	Consultative Committee on Space Data Systems
CD	Compact Disc
CFDP	CCSDS File Delivery Protocol
Co-I	Co-Investigator
CSDC	Cornell Science Data Center
DI	Deep Impact mission
DOM	Distributed Object Manager (database for files produced and used by DI)
DSMS	Deep Space Mission System, provided by IPN
DSN	Deep Space Network
DVD	Digital Versatile Disc
EDR	Experiment Data Record
GB	Gigabyte(s)
GDS	Ground Data System
GSE	Ground Support Equipment
HRI_IR	High Resolution Spectrometer - Infrared
HRI_VIS	High Resolution Imager - Visual
IPN	Interplanetary Network Directorate (at JPL)
IRAS	Infrared Astronomical Survey spacecraft
ITS	Impactor Targeting Sensor
JPL	Jet Propulsion Laboratory
MMO	Mission Management Office (part of IPN)
MOS	Deep Impact Mission Operations System
MRI	Medium Resolution Imager
NAIF	Navigation and Ancillary Information Facility (services provided under IPN)
NASCOM	NASA Communications
NAV	Navigation and related services provided by DSMS
NSSDC	National Space Science Data Center
PDS	Planetary Data System (of NASA)
PI	Principal Investigator
RS	Radio Science
SBN	Small Bodies Node of the Planetary Data System
SFDU	Standard Formatted Data Unit
SIS	Software Interface Specification
SPICE	Spacecraft, Planet, Instrument, C-matrix, Events
TC&DM	Telemetry, Command and Data Management (services provided under IPN)
TCM	Trajectory Correction Maneuver
TDS	Telemetry Data Server
TMOD	Tracking and Mission Operations Directorate (renamed to IPN)

TABLE OF CONTENTS

1. Introduction

This document defines the plans for archiving data from the Deep Impact (DI) mission with the Planetary Data System (PDS), including the design, generation, validation, and transfer of the data archive to the PDS. The archive will include raw and reduced instrument data, calibration and navigation data necessary for the interpretation of the instrument data, documentation, and related software.

Section 2 gives an overview of the Deep Impact mission including the Ground Data System by means of which the data stream will be converted into science data products. Section 3 provides an overview and design of the DI data archive. Section 4 describes the steps of the archive generation process. Section 5 specifies the roles of each of the participants in the archiving process, and assigns responsibility for each of the archiving functions. Section 6 provides the schedule for data archiving. Section 7 specifies the data release policy for the Deep Impact mission.

2. Overview of the Deep Impact Mission

2.1 Mission Overview

The launch window for Deep Impact opens in Dec, 2004. Deep Impact consists of two spacecraft – an impactor and a flyby. After launch, there will be a period during which targeting techniques will be tested and calibrations will be performed using the moon. The impact with comet 9P/Tempel 1 will occur in early July 2005. One day before impact, the impactor and flyby spacecraft separate. The flyby spacecraft then slows down to allow time to observe the cometary nucleus after the impact (about 14 minutes) and diverts so as to miss the nucleus by approximately 500 km. The instruments on the flyby spacecraft are body mounted so the spacecraft rotates to point the instruments at the nucleus during the approach. Some data are transmitted continuously in real time while all data are stored on board. When the spacecraft has rotated 45°, nominally at a range of 700 km from the nucleus, the rotation is stopped at which point dust shields have been rotated into the direction of the velocity vector to protect the spacecraft through the innermost coma. After closest approach, when the densest part of the coma has been transited, the spacecraft turns to take look-back observations of the comet. All data are transmitted to Earth within a few days after the encounter.

Earth-based imagery of the target are acquired both prior to and after the impact; these become a part of the DI archive, as do reprocessed data acquired years earlier from the Infrared Astronomical Survey (IRAS) spacecraft.

2.2 Ground Data System Overview

The DI Ground Data System is the mechanism by which the raw spacecraft data stream will be converted to science data products, including those to be archived with the Planetary Data System under project aegis. The DI Mission Operations System (MOS), distributed between the Jet Propulsion Laboratory in Pasadena, CA and Ball Aerospace Corp in Boulder, CO, will be responsible for monitoring the status of the spacecraft and payloads, commanding the spacecraft and payloads, coordinating real-time mission planning, operating the telemetry data services and producing navigation and ancillary data in the form of SPICE kernels. The MOS will receive packets from the DSN and place these on the Telemetry Data Server (TDS). The MOS CFTP process will produce reconstructed images from the image data and place these on the Distributed Object Manager (DOM). The Cornell Science Data Center (CSDC) will provide the initial processing, analysis and archive preparation of the science data. The CSDC will accept and process image files, command history files and navigation data, creating Experiment Data Records (EDRs). The CSDC will also receive and organize calibration files, and will coordinate with JPL navigation to develop the comet kinematics model and shape model. CSDC development will be carried out at Cornell University, but CSDC operations will take place at the MOS at JPL.

Once science EDRs have been produced by the CSDC they will be transferred to the PI team at the University of Maryland, where the content and format will be validated and the final archive volumes will be prepared.

A comprehensive description of the DI Ground Data System is provided in the DI Mission Operations Plan (Ref. 1). A data flow diagram for the downlink portion is shown in Fig. 1

3. The Deep Impact Archive

3.1 Overview

The DI archive will contain science data products from each of the instruments, instrument calibration data, command history data, navigation and ancillary data in the form of SPICE kernel files, software, and sufficient documentation of the data, software, and mission to enable scientists to understand and use the archive well into the future. To produce this archive a number of steps need to be carried out, including design of the archive structure and contents, generation of the archive components, peer review with the PDS, and final packaging and delivery. The science data products form the core of the archive; a list of the expected data products from each of the instruments is given in Appendix A. The data set collections to be archived are expected to be several gigabytes (GB) in size. The archive will be on-line at the PDS Small Bodies Node, consistent with current PDS practice. Several copies of a hard media archive will also be produced for deep archive purposes, using compact disks (CD) or digital versatile disks (DVD).

3.2 Archive Structure

The DI archive will be broken down into data set collections, one for each instrument, one for data sets deriving from more than one instrument (the MERGE data set collection), and one for SPICE data. A typical volume will contain data from a specified time interval. The top level directory of a volume will thus contain directories for each of the data set collections and directories for each of the additional components of the archive, as required by PDS. The MERGE data will be ordered by time first, then by instrument, and further divided by type of data, if relevant. Figure 2 illustrates the structure of a typical volume of the archive. Data types and volumes for each archive component and for the total archive are shown in Table 1. The directories at the top-level of each volume are given in Table 2.

Table 1
Data Volumes for Archive Components

Archive Component	Data Type	Data Volume (GB)
Imagers (HRI_VIS, MRI, ITS)	Raw Images Calibrated Images Calibrations Support Data Shape model	5.7
Spectrometer (HRI_IR)	Raw Spectra Calibrations Calibrated Spectra	.13
Radio Science	Trajectory estimates and supporting products used to determine Radio Science results.	.05
Earth based	Images Spectra	60
Supporting	Reprocessed data from IRAS	.02
MERGE	Shape models	.01
Ancillary	Mission history files SPICE Kernels	.01
Software	Calibration Algorithms Higher Level Software (as provided by Science Team)	.01
Documentation		.05
Total archive		66GB

Table 2
Top-Level Components of a Deep Impact Archive Volume

Directories	Contents
DOCUMENT	Text files serving as documentation for the archive.
CATALOG	The catalog objects (templates) required by PDS to document the mission, spacecraft, instruments, and data sets.
SOFTWARE	Software to be included with the archive.
INDEX	Index files to enable the user to find the data of interest.
CALIB	Calibration files. Calibrations may also be included within individual data sets.
GEOMETRY	Data necessary to describe the observing geometry, such as SPICE kernels. Includes spacecraft attitude data.
Instrument Data Set Collections:	
HRI_VIS	The high-resolution image data set collection.
HRI_IR	High resolution mapping spectrometer data set collection
MRI	The medium resolution image data set collection.
ITS	The Impact Imager data set collection
RS	The radio science data set collection.
MERGE	The collection of data sets originating from more than one instrument.
EARTH-BASED	Earth-based images of Tempel 1 acquired both pre- and post encounter

3.3 Volume Documentation Files

PDS requires a number of volume documentation files for each archive volume. One is a readme.txt–a text file describing the contents of the volume. Also required is voldesc.cat–a catalog of all the files residing on the volume. Each of the sub-directories under the top-level directory also requires one or more files to document the contents of that directory. The details of these files are specified in the PDS Standards Reference (Ref. 3).

3.4 The Data Set Collections

The list of expected data products from each of the DI instruments as provided by the science team members is given in Appendix A. The data products from each instrument will comprise a data set collection, and within each of these data set collections, the individual data products will be grouped into data sets. As an example, the planned grouping of data products into data sets for the High Resolution Imager is presented in Table 3. The data products from each of the other instruments will be similarly grouped into data sets comprising a data set collection.

Table 3
The HRI Image Data Set Collection

Data Sets	Data Products
Raw images	Raw images
Calibration images	Calibration images
Calibration files	Calibration files
Shape data	Control point network Shape model (1x1 degree, resolution -20m) Grid overlays for selected images Global digital image mosaic (6m/pix) with topographic overlay (8pix/deg)
Support data	Mission history file Updated pointing for all images Improved rotational elements for Tempel 1 Previous dust measurements, e.g., from IRAS

3.5 Safed Data

Packet data and some ancillary files will be assembled and placed on CD-R or DVD media for long term safekeeping in the event problems are discovered with the formally archived higher-level data products. Copies of this safed data (and allied documentation) will be provided to the PI, the CSDC and the NAIF node of the PDS.

These same data will be archived by JPL/IPN for a minimum of three years after end of mission.

4. The Archive Generation Process

The major steps to be followed in generation of the DI archive are described in this section. Responsibilities for generating archive components are specified in Section 5.

4.1 Archive Preparation

Science data products will be generated in PDS-compatible formats. This requires that each data file (data table or image file) be in a format approved by PDS and be accompanied by a PDS "label", actually a detached descriptive header file describing formally the content and structure of the accompanying data file. Ancillary data describing the observing conditions and spacecraft state when science data were acquired will be extracted from the packet data and SPICE kernels and placed in these PDS labels.

An extensive earth based archive of Tempel 1 data will be collected in both a pre and post encounter phase; these data will be included in the archive.

The source code of all software to be provided with the archive will be collected, documented and included in the archive.

Files documenting the archive components will be prepared by the parties generating the data. In general, all information necessary to interpret and use the data is to be included in the archive.

PDS standards call for the documentation of the mission, spacecraft, instruments, and data products with special files called “catalog objects.” Since the catalog objects take the form of a template that must be filled out with prescribed information, they are often referred to as “templates” even when they are already filled out. The required templates are the “mission template” describing the Deep Impact mission as a whole, the "instrument host template" describing the spacecraft, one “instrument template” for each instrument, and one “data set template” for each data set. These templates are to contain much of the information necessary to document the archive, and should make it possible for scientists to make correct use of the data in the future when the mission personnel are not available to support them. The PDS will fill in portions of the catalog objects, requiring only text descriptions of the mission, spacecraft, instruments, and data sets from DI personnel.

4.2 Archive Validation

Data validation falls into two types, validation of the data itself and validation of the compliance of the archive with PDS archiving requirements. The first type of validation will be carried out by the Science Team, and the second will be overseen by the PDS, in coordination with the Science Team. The delivery schedule of four separate delivery dates for different portions of the mission will facilitate validation by insuring that problems in the early deliveries are resolved by the time of the later deliveries.

The formal validation of data content, adequacy of documentation, and adherence to PDS archiving standards is finalized with an external peer review. The peer review will be coordinated by the PDS. The peer review process may result in "liens"–actions recommended by the reviewers or by PDS personnel to correct the archive. All liens must be resolved by the data set provider: the CSDC and Applied Coherent Technology Corporation (ACT) for level 1b data, the science team for higher-level data products and calibration algorithms (see Appendix C for data levels). PDS will do a final validation prior to packaging and delivery.

4.3 Archive Packaging and Delivery

Data delivery will take place in stages, as specified in Table 4. Each delivery will be made to PDS on a hard medium such CD or DVD. The final data delivery will incorporate the entire archive, including the earlier data deliveries

Table 4
Timeline for DI Project Archiving

Delivery date	Archive Products
09/30/2003	Earth based pre-encounter spectra and images.
03/31/2005	Calibration files and payload tests during checkout
12/31/2005	Earth based data leading up to impact. Spacecraft measurements through impact.
03/31/2006	Earth based post impact data.

5. Roles and Responsibilities

This section describes the roles and responsibilities of the personnel and organizations involved in generating, validating, transferring, archiving and distributing the DI archive.

5.1 Responsibilities of the DI Project

The DI archive consists of products generated by the project Mission Operations System (MOS) and by the Project Science Team, comprised of the PI (including subcontractor ACT Corp.), Co-Is, and the Cornell Science Data Center.

5.1.1 Responsibilities of the Project Mission Operations System

Essentially all elements of the DI operations team at JPL and Ball Aerospace and Technologies Corporation (BATC) contribute–directly or indirectly–to the DI archive. As such all MOS elements are responsible for ensuring the data provided by them are as complete and correct as possible under the terms of each element's contract with the DI project or NASA. Major MOS archiving responsibilities are described below.

a) The Deep Space Mission Systems (DSMS) is responsible for making packet and CCSDS file data available to the Project Science Team and other project teams via the TDS and DOM servers, respectively. This service includes assuring that 95+% of all data received at DSN stations are made available to the DI teams. The DSMS also provides images reconstructed from transfer frames; these are placed on the Distributed Object Manager (DOM) database. DI project elements needing these data are responsible for querying for the data from the TDS and/or DOM as needed. Query tools and/or instructions are provided by DSMS. The DSMS services are multimission services provided by JPL's Interplanetary Network Directorate (IPN).

The imager and spectrometer instruments' scientific data are provided as files from the telemetry transmitted to earth using the CCSDS File Delivery System (CFDP) protocol. These are placed in the project database (DOM) by the DSMS, from which they are retrieved by the CSDC.

DSMS is also responsible for producing a "safed" archive comprised of all packet data and a selection of important file products produced by DSMS, such as the SCLKvSCET file and the Predicted Events File (PEF). This "safed" archive will include SISs for the file products and appropriate documentation for all the contents. Its construction will generally follow PDS standards, but the product will not be peer reviewed or formally cataloged. Copies will be provided to the PI, the CSDC and the NAIF Node of the PDS.

b) The Navigation and Ancillary Information Facility (NAIF) is responsible for producing a full suite of SPICE kernels and preparing these for archival. NAIF will provide these SPICE files to the PI's subcontractor, ACT Corp., for inclusion on the DI digital archive volumes. (As the navigation node of the PDS, NAIF will maintain copies of these SPICE files and make them available to the science community, along with the associated SPICE Toolkit: but this is accomplished as a responsibility of the PDS.) NAIF multimission services are provided by JPL's IPN Directorate.

c) The DI Project Office will make available all non-proprietary and non-ITAR-restricted documents for possible inclusion on the DI archive volumes.

5.1.2 Responsibilities of the Project Science Team

The Project Science Team has the overall responsibility of setting observing priorities for the spacecraft instruments in order to meet the fundamental science goals of the DI project. The ensemble data from these observations constitute the raw science data–the fundamental element of the archive.

Each of the entities comprising the Science Team has major responsibilities in producing and validating the archive volumes; these are enumerated here.

a) Cornell Science Data Center

The CSDC is responsible for generating and validating the calibrated science data files, the comet shape and kinematic models, and the source code and associated documentation of software used to generate these data products. The CSDC will provide the source code and be responsible for its archiving; however, the CSDC will not support the code after the end of the mission (EOM). The software is quite important so that a future user can redo the calibration without recourse to the science teams.

The CSDC will participate in the PDS-sponsored peer review of archival products, and will take actions needed to clear any liens against the data it has provided for archival.

b) PI and CoIs

The PI has the ultimate responsibility for delivering to the project a complete and validated archive of all files necessary for final data calibration.

The PI and CoIs that generate derived digital data products delineated in Appendix A are responsible for producing archival quality data sets, including calibration data, relevant software, and documentation, all consistent with PDS standards.

The PI is responsible for clearing all liens on products produced by the science team that result from the PDS peer review process. The Co-Is will participate in this process if their data products are involved.

An integral part of the archive is the supporting earth based (EB) observations. The team leader of the earth-based observation team will ensure that data are collected in a timely and meaningful manner. The DI project will interact with ACT to ensure that proper PDS labels and documentation are provided with the EB data. This collection of EB data will include both pre- and post-impact observations.

c) ACT Corporation

The DI Science Team, through its PI subcontractor, ACT Corp., has the responsibility for producing all PDS-compliant archive volumes: “preliminary” for peer review and “final” for archival. This work will be coordinated by the PI at the University of Maryland. Approved copies of these “final” volumes will be distributed to the science team members, the PDS and the NSSDC.

ACT Corp. will prepare the Software Interface Specification (SIS) documents in consultation with the DI project. These are an invaluable documentation of the structure and content of the data products. These are needed both for internal use and for future users of the archive.

5.2 Responsibilities of the PDS

The Small Bodies Node (SBN) is the lead PDS node for interfacing with the DI mission and will be supported by the NAIF node (SPICE data) and the Central Node. Specific functions of PDS are listed below.

a) Consult on Archive Generation: Support the generation of the archive by advising the project/science teams on PDS archive standards, requirements and documentation needs. The SBN will support the data validation activity to ensure that the formal peer review process, a requirement for data ingestion into PDS, proceeds with a minimum of problems.

b) Conduct a formal peer review of the archive. This is a PDS mandated step before any data can be ingested into PDS.

c) Offer support to the PI, DI archive subcontractor (ACT Corp), and CSDC in the resolution of liens that arise in the course of the peer review.

d) Maintain the DI archive collection on-line for access by the planetary science community. PDS is also to offer expert advice to customers requesting help with the use of these products.

e) Replicate archive volumes for distribution to the NASA supported science community whenever physical media are judged to be appropriate

f) Provide a copy of the archive volume set to the National Space Science Data Center (NSSDC) for deep archive purposes, and for replication to serve any requests coming from the general public.

6. Schedule for Archive Generation, Validation, and Delivery

The principal archive elements, namely the science data products defined in Appendix A, will be generated during the course of the mission, as will many ancillary products such as SPICE files. The general guideline for Discovery missions is that they deliver archive quality volumes to PDS at intervals not exceeding six months after receipt of the data used to make the products contained on the volume.

The planned timeline for archive delivery to PDS is shown in Table 4. The final archive delivery is to be made 90 days after the end of the nominal mission in order to allow time for PDS review and lien resolution before the end of operations.

Following the delivery of archive volumes to PDS is a several-month-long period in which the data will be peer reviewed by PDS. Any liens that are identified by the peer review process will be rectified by the Project and the appropriate science team members before they cease operation (expected to be 90 days after the end of mission for science team). The DI project is responsible for resolving all liens against the final archive delivery. Final acceptance of the data by PDS will occur only after all liens have been cleared. The delivery of post-launch calibration data to the PDS will help to identify early in the mission any potential problems that can be addressed before the final archive is generated, thus avoiding liens on the data that require significant resources to correct.

7. Data Release Policy

There are no proprietary data rights for the DI Mission. Science team members do have a limited amount of exclusive time–not to exceed six months–for validation of data prior to delivery to the PDS.

Fully reduced, calibrated and corrected data products will be produced by the science team for delivery to PDS per the schedule given in Section 6. The PI and Team Leaders are responsible for coordinating all scientific investigations involving the use of calibrated data from their respective instruments and ensuring that all science data products are delivered in a timely fashion.

Appendix A. Science Data Products

Imagers

Validated raw images in PDS format with ancillary information.
Complete pre-flight calibration files with documentation.
Complete in-flight calibration files with documentation.
"Best" final calibration files, calibration algorithms, and optimum parameters.

Mission history file (objectives of sequences, anomalies, etc.)
(an observing log indicating what has changed and why.)
Support data:
A) Updated pointing (all images).
B) Improved rotational elements.
C) Control point network.

Spectrometers

Validated raw long slit data, in PDS format, with ancillary information.
Complete pre-flight calibration files with documentation.
Complete in-flight calibration files with documentation.
"Best" final calibration files, calibration algorithms, and optimum parameters.
Individual I/F calibrated spectra in PDS format with ancillary information.
Mission history file (objectives of sequences, anomalies, etc.)

Radio Science

Tracking data files
Ephemeris files
Tracking system model files

Earth based

Images and spectra in standard PDS format

Spacecraft Attitude

Attitude control system changes due to dust impacts. Note: this set of data is part of the SPICE ancillary data collection, contained in the C-kernel.

Appendix B. Glossary of Terms

Catalog object	A PDS-required file formally documenting the details of a mission, spacecraft, instrument, or data set
Data product	A single instance of the output of an instrument, such as an image or spectra. For instruments having a continuous output (such as a particle counter) there need be an artificial binning applied to create discrete data products. A product is described as a PDS data object.
Data set	Normally a collection of data products of a single type–such as images or spectra–for a given mission phase. In some cases (e.g. for Radio Science and SPICE) a data set may include multiple types of data products having a common purpose or function.
Data set collection	A collection of data sets typically covering an entire mission
Label	An attached or detached header which formally describes the structure and content of a data product
Lien	An action recommended by reviewers or PDS personnel to correct the archive
Template	Same as a catalog object
Volume	A single CD, DVD, or other volume of a storage medium
Volume set collection	A complete collection of all the individual volumes comprising the entire data set collection

Appendix C. Data Level Definitions

NASA Level	Description:
0	The raw data as delivered to/from the spacecraft. Corresponds to CODMAC level 1
1	Uncompressed data that have been cleaned and merged, time ordered, and quality flagged in PDS format. Corresponds to CODMAC level 2.
2	Level 1 data that is geo-located, co-added, and calibrated. Corresponds to CODMAC level 4.
3	Standard products from one or more passes, completely defined, validated, and produced immediately after the observation. Corresponds to CODMAC level 5.

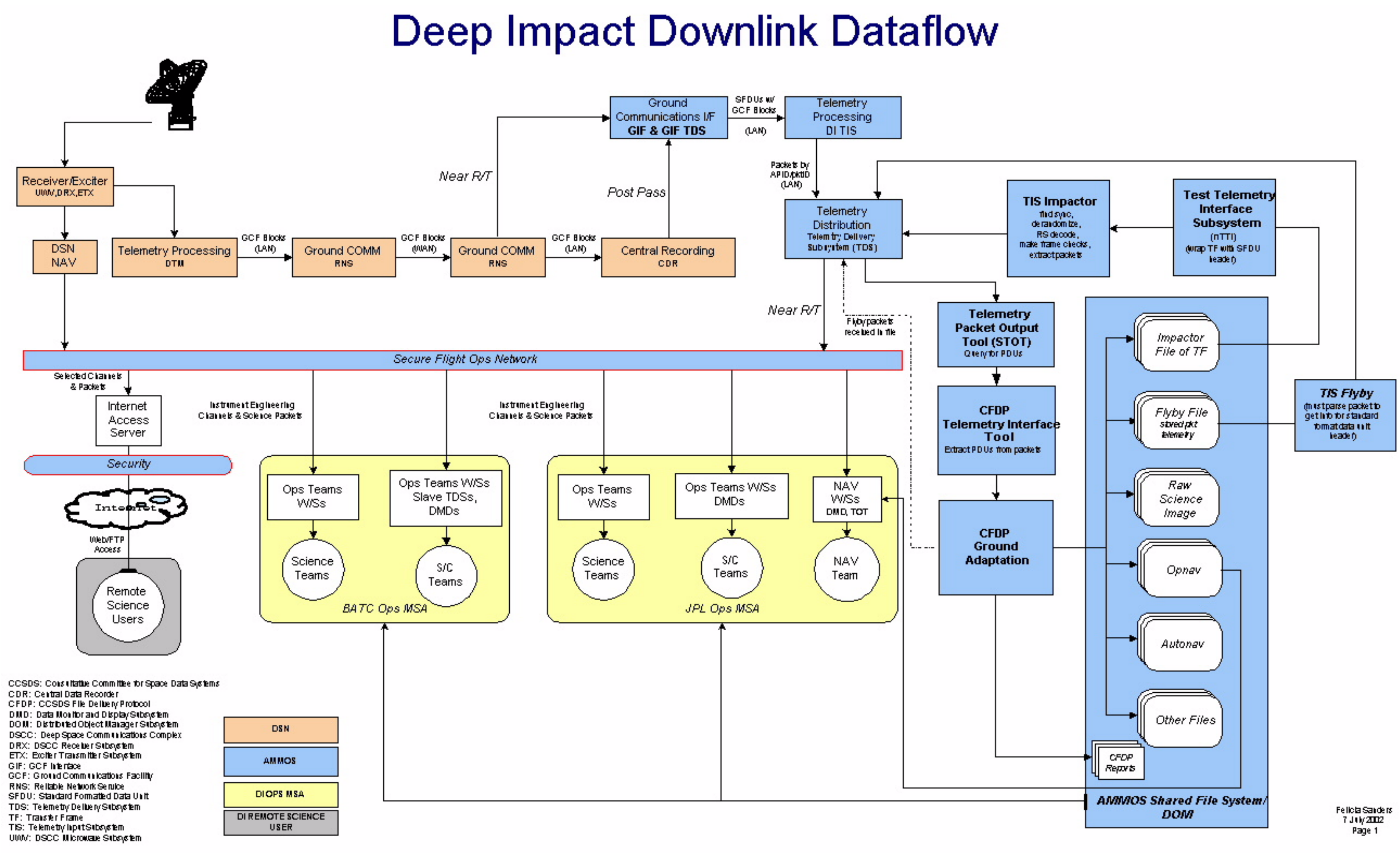

Figure 1 DI Ground Data System—Downlink Data Flows

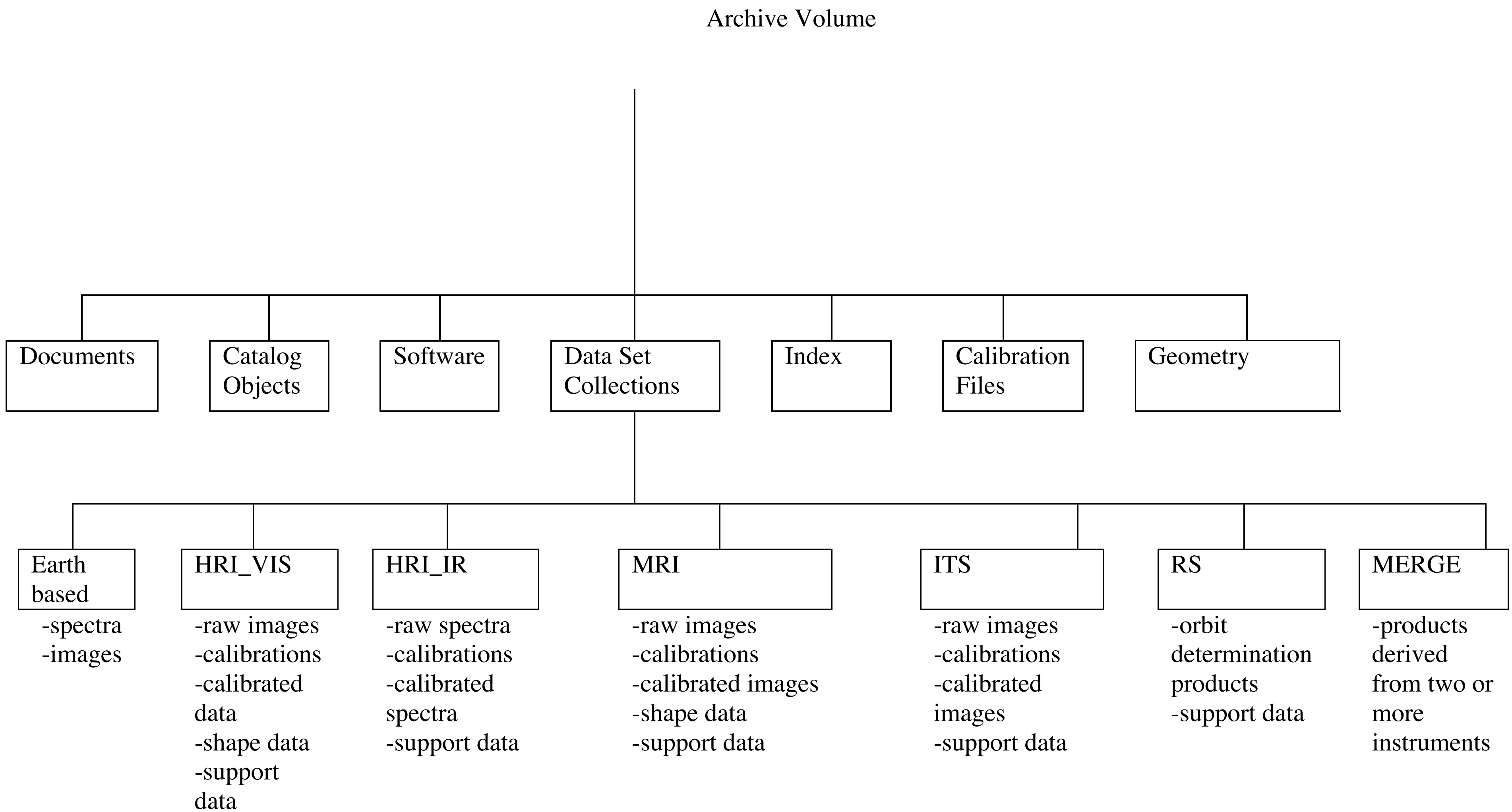

Figure 2. Structure of a Typical Volume of the Deep Impact Archive