New Horizons Data Management and Archiving Plan

NOVEMBER 2005

SwRI® Project 05310

Document No. 05310-DMAP-01

Contract NASW-02008

Prepared by

SOUTHWEST RESEARCH INSTITUTE®
Space Science and Engineering Division
6220 Culebra Road, San Antonio, Texas 78228-0510
(210) 684-5111 • FAX (210) 647-4325

New Horizons Data Management and Archiving Plan

SwRI Project 05310

Document No. 05310-DMAP-01

Contract NASW-02008

Prepared by: _____ Date: _____
Paul E. Meade (SwRI)

Reviewed by: _____ Date: _____
Leslie A. Young, Deputy Project Scientist (SwRI)

Approved by: _____ Date: _____
S. Alan Stern, Principal Investigator (SwRI)

Approved by: _____ Date: _____
Harold Weaver, Project Scientist (JHU-APL)

Approved by: _____ Date: _____
Glen Fountain, Project Manager (JHU-APL)

Approved by: _____ Date: _____
Michael A'Hearn, Node Manager,
Planetary Data System Small Bodies Node

Approved by: _____ Date: _____
John Andrews, SOC Manager (SwRI)

Approved by: _____ Date: _____
Laverne Hall, Project Manager,
Planetary Data System

Approved by: _____ Date: _____
P. Brian Gupta, SwRI Institute Quality Systems

Approved by: _____ Date: _____
L. D. McCullough, SwRI Project CM

Space Science and Engineering Division
Southwest Research Institute
P. O. Drawer 28510
6220 Culebra Road
San Antonio, Texas 78228-0510
(210) 684-5111

TABLE OF CONTENTS

REVISION NOTICE

Draft: 1: April 2004
Draft 2: February 2005
Initial Issue: November 2005

1. INTRODUCTION

This document defines the process of archiving data from the *New Horizons* 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 science data and navigation and housekeeping data necessary for the interpretation of the science data, as well as documentation (including documented software source code and algorithm definitions). The document in its current form is derived from an earlier version that appeared as an appendix to the *New Horizons* Concept Study Report.

Section 3 of this document gives an overview of the *New Horizons* mission including the Ground Data System by means of which the data stream will be converted into science data products. Section 4 specifies the roles of and assigns responsibilities to each of the participants in the archiving process and provides an overview of the steps necessary to produce the *New Horizons* data archive. Section 5 outlines the upper-level structure of the archive itself. Details of the archive structure down to the file level will be determined at a later date as the data products from each instrument are fully defined. Section 6 provides the schedule for data archiving, and section 7 specifies the data release policy for the *New Horizons* mission.

For reference, a list of the *New Horizons* science data products expected from each instrument, a glossary of acronyms used in this document, and the *New Horizons* data level definitions are given in the appendices.

Note that in its current form this Data Management and Archiving Plan applies only to the *New Horizons* primary mission (i.e., the Pluto/Charon encounter) and all preceding mission phases (the two cruise phases and the early mission Jupiter encounter). Although it is anticipated that a *New Horizons* extended mission will include one or more encounters with Kuiper Belt Objects (KBOs), it is not currently possible to accurately predict either the timing of these events or the data volumes involved; furthermore this mission extension has not yet been approved by NASA Headquarters.

2. APPLICABLE DOCUMENTS

New Horizons Mission Science Definition (MSD) 7399-9000, October 27, 2003
New Horizons Mission Operations Center to Science Operations Center Interface Control Document, November, 2004.
New Horizons Navigation to SOC ICD. 05310-SOCNAV, in review.
New Horizons SOC to Instrument Pipeline ICD, 05310-SOCINST-01, September, 2005..
Planetary Data System Proposer's Archive Guide (PAG), JPL D-26359, version 1.0, June 15, 2003
PDS Data Preparation Workbook (DPW), JPL D-7669, Part 1, version 3.1, February 17, 1995
PDS Standards Reference (SR), JPL D-7669, Part 2, version 3.6, August 1, 2003

3. OVERVIEW OF THE *NEW HORIZONS* MISSON

3.1 Mission Background

New Horizons is the first mission in NASA's New Frontiers program of the Office of Space Science. *New Horizons* was selected in response to NASA AO 01-OSS-01. *New Horizons* is a PI led mission.

In the baseline mission plan, the *New Horizons* spacecraft will be launched in January 2006 and will execute a Jupiter gravity assist in early 2007. Jupiter encounter science data will be downlinked over the following few months. If launch does not occur until February 2006, *New Horizons* will proceed directly to Pluto/Charon without a Jupiter gravity assist and the Jupiter encounter will not occur. The Pluto/Charon encounter will occur in 2015 or 2016 on a trajectory including Jupiter gravity assist, but may occur as late as 2020 if a direct trajectory is required.

If launch cannot be achieved during the baseline launch window in 2006, a backup mission launch window is available in February 2007. The backup launch window requires a direct trajectory to Pluto/Charon, with encounter occurring in 2019 or 2020.

Downlink of Pluto/Charon encounter data to Earth will take place over the nine months following the encounter. Shortly after the Pluto/Charon encounter, *New Horizons* can be retargeted to its first encounter with a Kuiper Belt Object (KBO). If an extended mission is approved, *New Horizons* will encounter one or two KBOs prior to reaching 50 AU from the Sun.

The detectors aboard *New Horizons* include the Alice ultraviolet spectrometer, the Ralph-MVIC multispectral imager, the Ralph-LEISA near-IR imaging spectrometer, the REX radio science package, the LORRI long focal length imager, the PEPPSI and SWAP particles and plasmas instruments, and the SDC interplanetary dust detector. The REX experiment will use ultrastable oscillators integrated into the *New Horizons* telemetry system to determine the atmospheric profile of Pluto. The LORRI experiment consists of a high resolution panchromatic imager. SWAP and PEPPSI are, respectively, a low-energy plasma and solar wind instrument and a medium-energy particle spectrometer. The final instrument, SDC, is designed to count impacts of interplanetary dust on its detector throughout the duration of the mission.

3.2 Ground Data System

The *New Horizons* Ground Data System will convert the raw spacecraft data stream to science data products. The Mission Operations Center (MOC), located at APL, will receive telemetry frames from DSN and process them through CODMAC Level 1 (*New Horizons* Levels 0, 0a, and 0b; see Appendix C for CODMAC and *New Horizons* data level definitions). The MOC provides the CODMAC Level 1 data to the Science Operations Center (SOC) in the form of Supplemented Telemetry Packets (STPs), which consist of standard CCSDS telemetry packets with prepended blocks of supplementary data. Navigation data, including spacecraft and planetary ephemerides, and spacecraft pointing data, will be relayed to the SOC in SPICE format. The *New Horizons* SOC has two principal nodes, located at SwRI-Boulder and APL.

The SOC will support the Mission Science Team (MST) processing and analysis of the science data. It will provide easy access to all the data required by the MST and the MOC. The SOC will accept and process telemetry, command history, and navigation data to produce decommutated raw data (CODMAC Level 2), creating the telemetry and calibration file archive. The SOC will archive the decommutated raw

data with PDS. Also, the SOC will coordinate with the MOC and the navigation team to maintain the planetary kinematics, gravity, and shape model datasets.

The SOC will process the decommutated raw data using automated software and calibration files provided by the Instrument Teams to produce provisional calibrated data products (provisional CODMAC Level 3 or 4). The individual Instrument Teams are responsible for either approving the provisional data products as archival data products for PDS or independently producing CODMAC Level 3 or 4 files with more sophisticated analyses (archival CODMAC Level 3 or 4 files). In general, only the archival data files will be archived to PDS (see sections 4.2.1 and 4.2.2, below). Higher-level derived data products (e.g., maps and mosaics), equivalent to CODMAC Level 5, are to be produced by the Science Theme Teams (STT) of the MST and archived by the SOC to PDS.

4. ARCHIVING FUNCTIONS

4.1 Overview

The section describes the structure and content of the *New Horizons* data archive, as well as the responsibilities of the different teams comprising the *New Horizons* project in producing the components of the data archive.

The *New Horizons* archive will contain science data products from each of the instruments, spacecraft and instrument housekeeping telemetry, navigation and geometry data from the SPICE information system, algorithm definitions and source code for data handling and calibration software, and sufficient documentation of the data, software, instruments, and mission to enable future scientists to understand and use the archive.

Production of the *New Horizons* archive involves design of the archive structure and contents, generation of the archive components, component validation, and final packaging and delivery. The science data products form the core of the archive, and a preliminary list of data products expected from each of the instruments is given in Appendix A.

4.2 Roles and Responsibilities

The responsibilities for data archive generation, validation, delivery, review, and storage and maintenance are distributed among a number of different organizations both within the *New Horizons* mission and outside of it. These organizations include the *New Horizons* SOC, Instrument Teams, and Science Theme Teams, as well as the Planetary Data System Central Node (CN) and Small Bodies Node (SBN) and the National Space Science Data Center (NSSDC). The following sections outline the specific responsibilities of these contributors.

4.2.1 SOC

The SOC is responsible for producing and validating the CODMAC Level 2 science data files from Level 1 science data packets provided by the MOC. The SOC will deliver to PDS the Level 2 science data files and calibration files, as well as the source code and associated documentation for the software used to generate the data products. It will also collect from the MOC, provide to the Science Theme Teams, and deliver to PDS the spacecraft ephemeris and spacecraft attitude records, a history of all commands and spacecraft housekeeping files, and planetary shape and kinematics models.

The SOC shall create provisional CODMAC Level 3 data products, using automated data processing pipelines provided by the instrument teams. In general, these SOC-produced provisional data products

will not be archived with PDS. However, in the event that an Instrument Team cannot produce archival CODMAC Level 3 data products (see section 4.2.2, below) in time to meet a scheduled PDS delivery, the provisional data products will be delivered instead.

The SOC will prepare the Archive Interface Document (AID), which describes the archive structure and content both for internal use and for future users of the archive. The AID will necessarily evolve as data product definitions are further developed and refined, and the SOC will update and maintain the AID to ensure that it accurately reflects the current state of the data product definitions.

The SOC shall coordinate the delivery of all CODMAC Level 2 and 3 data products to the PDS. As described below (sections 4.2.2 and 4.2.3), the Instrument Teams and Science Theme Teams will deliver data products to the SOC, and the SOC will assemble the delivered data products and package the final archive volumes on physical media, such as CD-ROMs or DVDs, for delivery to PDS.

The SOC shall be responsible for clearing all liens generated by the review process on products produced by the SOC (CODMAC Level 2 data products, and Level 3 data products in cases where these products are archived with PDS). However, liens on data products which are delivered to PDS by the SOC but which are actually produced by the Instrument Teams and/or Science Theme Teams shall be cleared by the producer team, not by the SOC.

4.2.2 Instrument Teams

The *New Horizons* project includes Instrument Teams for the Ralph (MVIC and LEISA), Alice, REX, LORRI, PEPSSI, SWAP, and SDC detectors. Each Instrument Team is responsible for delivering to the SOC a complete and validated archive of all files necessary for final data calibration (CODMAC Level 3) produced by the team, along with algorithm definitions and software source code for calibration and associated documentation. SDC is an Education/Public instrument, and, as such, will deliver an archive on a best-effort basis. Calibration software source code shall be provided in one of the programming languages specified in the *New Horizons* SOC to Instrument Pipeline ICD documents. Note that raw instrument telemetry will not be included in the *New Horizons* PDS archive. Also, pre-launch instrument data shall not be included in the PDS archive, except for those which the Instrument Teams designate as necessary for calibration of downlinked science data.

Each Instrument Team shall be responsible for providing the SOC with pipeline data calibration software suitable for calibrating instrument data in an automated environment. This software shall comply with interface specifications developed by the SOC in consultation with the Instrument Teams. The automated pipeline calibration software shall be used by the SOC in order to produce provisional CODMAC Level 3 data products (see section 4.2.1, above).

Each Instrument Team shall be responsible for generating and validating the archival CODMAC Level 3 data products using CODMAC Level 2 data products made available by the SOC. The Instrument Teams shall deliver these data products to the SOC, consistent with the PDS delivery schedule outlined in section 6. The SOC shall in turn deliver the complete data archive to PDS.

The team leader of each Instrument Team is responsible for clearing all liens generated by the PDS review process on products produced by his/her team.

4.2.3 Science Theme Teams

The *New Horizons* Mission Science Team (MST) is organized into four Science Theme Teams (STT): Geology and Geophysics Imaging (GGI, led by J. Moore), Surface Composition Mapping (COMP, led by

D. Cruikshank), Atmospheric Studies (ATM, led by R. Gladstone), and Particles & Plasmas (P&P, led by F. Bagenal). Each STT team leader is responsible for delivering to the PDS a complete and validated archive of all higher level data products (CODMAC Level 5) produced by the team, along with source code for the software used to produce the data products and associated documentation. GGI is responsible for MVIC and LORRI data products. COMP is responsible for LEISA data. ATM is responsible for ALICE and REX data. P&P is responsible for SWAP, PEPSSI, and SDC data. The Science Theme Teams shall deliver these data products to the SOC, consistent with the PDS delivery schedule outlined in section 6. The SOC shall in turn deliver the complete data archive to PDS.

The team leader of each science team shall be responsible for clearing all liens generated by the review process on products produced by his/her team.

4.2.4 PDS Small Bodies Node (SBN)

PDS has designated the Small Bodies Node (SBN) as the lead node for interfacing with the *New Horizons* mission. Designation of a lead node greatly simplifies the PDS interface. The lead node will be supported by other PDS nodes, which may include the PPI node (particles and plasmas data), the radio science subnode (radio science data), the imaging node (imaging data), the atmospheres node, or the NAIF node (SPICE data). Specific functions of PDS SBN are to:

a) Support the generation of the archive by advising the project/science teams on PDS archive standards, requirements and documentation needs. PDS will also 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, as mandated by PDS prior to acceptance of archive data.

c) Advise *New Horizons* SOC, Instrument Teams, and Science Theme Teams in the resolution of liens that arise in the course of the peer review.

The designated PDS SBN contacts for *New Horizons* are as follows:

- Mike A'Hearn for science and policy issues, with Dave Tholen (U. Hawaii) as backup
- Stephanie McLaughlin for technical issues, with Anne Raugh (SBN) as backup

4.2.5 PDS Central Node (CN)

Although most of the contact between *New Horizons* and PDS will occur through the PDS SBN, the PDS Central Node (CN) has some unique responsibilities for maintaining and disseminating the data archive. These are to:

1) Produce archive volumes for distribution to the NASA-supported science community.

2) Provide the data archive volumes to NSSDC.

The designated PDS CN contact for *New Horizons* technical issues is Tyler Brown.

4.2.6 National Space Science Data Center (NSSDC)

NSSDC is responsible for long-term preservation of *New Horizons* data and for filling large data orders to the science community per the Memorandum of Understanding, dated January 13, 1994, between the PDS and NSSDC. New Horizons does not have any responsibility for direct interactions with the NSSDC.

4.3 Archive Generation

Responsibility for generating archive components is specified in Section 5. Science data products will be generated in PDS compatible formats (e.g., FITS image and table files). Each data file (data table or image file) will be in a format approved by PDS and will be accompanied by a PDS "label," which is a detached header file describing the content and structure of the accompanying data file. Additional data necessary to interpret the data (e.g., spacecraft ephemeris and attitude records, command histories, and spacecraft housekeeping files) will be provided as ancillary archive components. All software source code used for archive generation will be collected in the PDS and documented. In addition, 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 shall be included in the archive.

The PDS "catalog objects" are files that briefly summarize the mission, spacecraft, instruments, and data products. These files are loaded into the PDS Central Node database to facilitate online searches and convey to users the nature of the data set collections in the archive. The catalog objects take the form of templates which must be filled out with prescribed information. The required catalog objects are the “mission template,” describing the *New Horizons* 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 will contain information needed to document the archive and enable future scientists to make correct use of the data when mission personnel are no longer available to support them. The PDS will fill in the formal portions of the catalog objects, requiring only text descriptions of the mission, spacecraft, instruments, and data sets from *New Horizons*.

4.4 Archive Validation

Data validation falls into two types, validation of the actual data, and validation of the compliance of the archive with PDS archiving requirements. The first type of validation will be carried out by the Instrument Teams and Science Theme Teams, and the second will be overseen by the PDS, in coordination with the Mission Science Team. The schedule of PDS deliveries will facilitate validation by ensuring that problems in the early deliveries are resolved by the time of the later deliveries and the final archive.

The formal validation of data content, adequacy of documentation, and adherence to PDS archiving standards is subject to external peer review. The peer review will be scheduled and 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 dataset provider: the SOC for CODMAC Level 2 data, the Instrument Teams for CODMAC Level 3 or 4 data, calibration data, and calibration algorithms, and the Science Theme Teams for higher level data products (CODMAC Level 5). Once the liens are cleared, PDS will do a final validation prior to packaging and delivery.

4.5 Final Packaging and Delivery

The *New Horizons* SOC shall be responsible for assembly, packaging, and delivery of all archive data to PDS. Responsibilities of the Instrument Teams and Science Theme Teams for delivering archive data to

the SOC are delineated in previous sections of this document. The SOC will deliver archive data sets to PDS on acceptable permanent storage media, such as CD-ROMs or DVDs.

The archive delivery schedule for *New Horizons* is outlined in Table 3 in section 6 of this document (with PDS delivery dates highlighted). Major deliveries are scheduled after the end of data receipt from the Jupiter and Pluto/Charon encounters. Additional minor deliveries are scheduled during the lengthy second mission cruise phase between Jupiter and Pluto/Charon, in order to archive data collected during the annual 50-day checkouts.

Calibrated scientific data (CODMAC Level 3 or 4) will be produced at two different calibration levels. Provisional CODMAC Level 3 (or 4) data will be produced at the SOC using automated calibration pipelines provided to the SOC by the instrument teams. The provisional CODMAC Level 3 (or 4) data products will not generally be archived to PDS, but will provide a contingency in the event that production difficulties delay or prevent the creation of archival CODMAC Level 3 (or 4) data products. Archival CODMAC Level 3 (or 4) data products will generally be produced by the instrument teams at their home institutions subsequent to the production of the provisional data products. This allows the instrument teams to fine-tune their calibrations and provide data products with improved calibrations while still ensuring that scientific-quality data products are available to the community in a timely fashion. Archival CODMAC Level 3 (or 4) data products will be archived at the same time as derived data products (CODMAC Level 5), as reflected in the schedule in section 6.

Data delivery for the *New Horizons* primary mission will take place in 5 major stages, as indicated in Table 3. There will also be at least 2 minor data deliveries during the lengthy second mission cruise phase, to accommodate instrument data collected during the preceding 50-day annual checkouts. The 5 major data deliveries will be divided between the Jupiter Encounter and the Pluto/Charon Encounter, with Jupiter Encounter data in the first two deliveries and Pluto/Charon Encounter in the latter three. The PDS delivery schedule for all data is included in Table 3. Delivery dates based on the baseline mission plan are highlighted.

5. THE *NEW HORIZONS* ARCHIVE

5.1 Overview

The *New Horizons* archive volumes will be divided into data set collections, one for each detector (MVIC, LEISA, ALICE, REX, PEPSSI, SWAP, LORRI, and SDC), one for higher-order data products derived from data from multiple detectors (MERGE), 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 directories in the top level directory of a volume are given in Table 1.

Table 1
Top-Level Components of a *New Horizons* Archive Volume

Directories	Contents
DOCUMENT	Text files serving as documentation for the archive.
CATALOG	The catalog objects required by PDS to document the mission, spacecraft, instruments, and data sets.
SOFTWARE	Source code and documentation for software to be included with the archive.
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.
INDEX	Index files to enable the user to find the data of interest.
MVIC	The Ralph-MVIC data set collection.
LEISA	The Ralph-LEISA data set collection.
ALICE	The Alice data set collection.
REX	The radio science data set collection.
SWAP	The SWAP data set collection.
PEPSSI	The PEPSSI data set collection.
LORRI	The LORRI data set collection.
SDC	The SDC data set collection.
MERGE	Higher-order data products derived from more than one instrument data source.

5.2 Archive Content

The preliminary list of expected data products from each of the *New Horizons* detectors 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.

5.3 Archive Data Volume

Data volume estimates for the *New Horizons* mission are given in Table 2, broken down by detector (or component) and mission phase (Commissioning / Cruise 1, Jupiter Encounter, Cruise 2 annual checkouts, and Pluto-Charon Encounter). The estimates in Table 2 for planetary encounters are scaled from the raw data volumes returned from the spacecraft by a factor of 11. This overall scaling factor incorporates the following:

Archive Component	*Size*	*Description*
CODMAC Level 2	2 x Raw	Decommutated Raw Data Data Quality Flags
Archival CODMAC Level 3 (4)	3 x Raw	Calibrated Data Data Uncertainty Data Quality Flags
CODMAC Level 5	6 x Raw	Higher-Order Data Products (Note: This is an ad-hoc estimate as the actual ratio of higher-order data products to raw data is currently unknown and will vary from detector to detector.)
Total	11 x Raw	

Note that a scaling factor of only 5 is used for Commissioning and Annual Checkout data volumes, for which it is assumed that the volume of CODMAC Level 5 data products will be negligible. The data volume estimate for SPICE data is twice the size of the aggregate SPICE files for the mission, because both predicted and after-the-fact (reconstructed) spacecraft ephemeris and attitude kernels will be included in the archive. The total estimated data volume for the nominal *New Horizons* mission 482.8 Gbits, where a gigabit (Gbit) shall be interpreted as 10^9 bits. This is equivalent to 60.4 gigabytes (GB), where a gigabyte shall be interpreted as 10^9 bytes.

Table 2
Data Volume Estimates for Archive Components (Based in Science Activity Plans)

Archive Component	Data Type Examples	Estimated Archive Volume (Gbits[1])				
		Commissioning	Jupiter	Annual Checkouts	Pluto / Charon	Total
MVIC (Ralph)	Raw Images Instrument housekeeping Calibrations Calibrated Images Image Mosaics Support Data	4.0	17.6	0.5	16.5	38.6
LEISA (Ralph)	Raw Spectral Images Instrument housekeeping Calibrations Calibrated Spectra Images Image Cubes	2.7	220.0	0.3	82.5	305.5
ALICE	Raw Spectra Instrument housekeeping Calibrated Spectra Atmospheric Profiles	0.7	61.6	0.2	3.3	65.8
REX	Raw Phaseshift, Intensity Data Instrument housekeeping Calibrations Doppler Data Atmospheric and Ionospheric Profiles	1.1	3.3	0.4	1.1[2]	5.9[2]
LORRI	Raw Images Instrument housekeeping Calibrations Calibrated Images Image Mosaics Support Data	5.7	30.8	1.9	0.8	39.2
SWAP	Raw Counts Solar Wind Parameters	0.5	7.7	1.2	1.1[2]	10.5[2]
PEPSSI	Raw Counts Particle Spectra, Angular Distributions	5.4	5.5[2]	1.0	1.1[2]	13.0[2]
SDC	Raw Counts Particle Size Distribution	0.5	1.1[2]	0.1	1.1[2]	2.8[2]
Navigation	SPICE Kernels	0.1	1.0	0.1	0.3	1.5
Software	Calibration Algorithms Higher Level Software (as provided by Science Teams)	0[3]	0[3]	0[3]	0[3]	0[3]
Documentation	Catalog files, Mission History Files	0[3]	0[3]	0[3]	0[3]	0[3]
Total archive		20.7	348.6[2]	5.7	107.8[2]	482.8[2]

[1]The term gigabit (Gbit) as used here shall be interpreted as 10^9 bits.
[2]These values have increased uncertainty due to incomplete encounter sequencing.
[3]Values of 0 for ancillary data are intended to indicate that the data volume is expected to be negligible compared to the scientific data

These estimates were derived based on the following assumptions:

1) Three classes of scientific data will be archived: decommutated raw data (CODMAC Level 2), archival calibrated data (CODMAC level 3 or 4), and derived data products (CODMAC Level 5).

2) The volume for each class of data can be expressed as a simple multiple of the raw downlinked instrument data volume as follows:

   - Decommutated Raw Data: 2x Raw Data (Data plus Quality Flag)
   - Archival Calibrated Data: 3x Raw Data (Data plus Uncertainties plus Quality Flag)
   - Derived Data Products: 6x Raw Data
   - Archive Total: 11x Raw Data

   Note that the 6x multiplier for Derived Data Products is a very rough estimate – it is not currently possible to accurately estimate the volume of Derived Data Products for each instrument as these data products have not yet been fully defined.

3) The volume of spacecraft attitude and navigation (ephemeris) data will be twice the size of the total expected SPICE kernels for the mission, since both predicted and after-the-fact (reconstructed) kernels will be archived.

4) It is assumed that the volume of software and documentation, although not zero, is negligible compared to the volume of scientific data.

5.4 Archive Design

The dataset to be archived by the *New Horizons* project will be organized on a number of different levels. The highest-level organization will be by mission phase, including Commissioning / Cruise 1 (including pre-launch calibration data), Jupiter Encounter, Cruise 2, and Pluto-Charon Encounter phases. A separate archive volume will correspond to each mission phase.

Within each archive volume, the next level of organization will be by detector (Alice, LORRI, PEPSSI, Ralph-LEISA, Ralph-MVIC, REX, SDC, and SWAP), including first-level directories for calibration files, catalog files, documents, geometry, and index files (e.g., CALIB, CATALOG, DOCUMENT, GEOMETRY, and INDEX). At this level there will also be a first-level MERGE directory for higher-order derived data products involving data from more than one instrument.

The dataset to be archived from the *New Horizons* project will therefore be ordered first by time (in terms of mission phase), then by instrument (as data set collections within each volume), and further divided by type of data products. At the deepest level of the archive, data will be organized in order of the Mission Elapsed Time (MET) at which the data were taken. Figure 1 illustrates the structure of a typical volume of the archive. The details of what components are included in the archive and how they are grouped into data sets, subdirectories, and files comprise the design of the archive. The final arrangement of the archive down to the file level will be specified prior to Jupiter encounter.

```
root of a New Horizons archival volume
   |
   |- AAREADME.TXT              text file describing volume
   |- ERRATA.TXT                cumulative errors and notes for volume set
   |- VOLDESC.CAT               structured text describing volume
   |
   |- CALIB                     directory for calibration files
   |    |- CALINFO.TXT          text file describing directory contents
   |    |- [calibration files]  instrument calibration files
   |    |- *.LBL                corresponding detached PDS labels
   |
   |- CATALOG                   directory of 'catalog' files
   |    |- CATINFO.TXT          text file describing directory contents
   |    |- MISSION.CAT          text file describing mission
   |    |- INSTHOST.CAT         text file describing instrument host
   |    |- INST.CAT             text file describing instrument
   |    |- DATASET.CAT          text file describing data set
   |    |- PERSON.CAT           text file listing contributors to archive
   |    `- REF.CAT              text file of references cited in other files
   |
   |- DOCUMENT                  directory containing documents
   |    |- DOCINFO.TXT          text file describing contents of directory
   |    |- AID.TXT              volume and data product Archive Interface Document
   |    |-   *.TXT              additional documentation files
   |
   |- GEOMETRY                  directory containing geometry files
   |    |- GEOMINFO.TXT         text file describing contents of directory
   |    |- [geometry files]     SPICE ephemeris and attitude files
   |    |- *.LBL                corresponding detached PDS labels
   |
   |- INDEX                     directory with tables of contents files
   |    |- INDXINFO.TXT         text file describing directory contents
   |    |- INDEX.TAB            table of contents for the volume
   |    |- INDEX.LBL            label for INDEX.TAB
   |    |- CUMINDEX.TAB         cumulative table of contents for volume set
   |    `- CUMINDEX.LBL         label for CUMINDEX.TAB
   |
   |- MVIC                      directory for MVIC data
   |    |- [table files]        FITS data tables
   |    |- [image files]        FITS image files
   |    |- *.LBL                corresponding detached PDS labels
   |
   |- LEISA             directory for LEISA data
   |    |-     ...
   |
   |- ALICE             directory for ALICE data
   |    |-     ...
   |
   |- REX               directory for REX data
   |    |-     ...
   |
   |- LORRI             directory for LORRI data
   |    |-     ...
   |
   |- SWAP              directory for SWAP data
   |    |-     ...
   |
   |- PEPSSI            directory for PEPSSI data
   |    |-     ...
   |
   |- SDC               directory for SDC data
   |    |-     ...
   |
   |- MERGE             directory for higher-order multi-instrument data products
        |-     ...
```

Figure 1. General structure of a typical volume of the *New Horizons* archive.

5.5 Volume Documentation Files

PDS requires a number of volume documentation files for each archive volume, including aareadme.txt, a text file describing the contents of the volume, and voldesc.cat, a machine readable file with a catalog of all dataset IDs residing on the volume. Each of the directories under the top level directory also requires one or more documentation files to document the contents of that directory. The details of these files are specified in the PDS Standards Reference. The files included in the data set collection for each of the eight sensors are listed in Appendix A.

5.6 Data Set Collections

The preliminary list of expected data products from each of the *New Horizons* sensors 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. Final list of data products from each instrument will be maintained in the *New Horizons* Archive Interface Document(s).

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 timeline for archive delivery to PDS is included in Table 3, and must take into account both the time required for downlink and that required for processing and validation. Dates for data deliveries to PDS are highlighted in Table 3, and include 2 post-Jupiter deliveries, 3 post-Pluto/Charon deliveries, and 2 minor deliveries during the second mission cruise phase.

Following data delivery to PDS, the data will be peer reviewed by PDS. Liens that are identified by the peer review process will be rectified by *New Horizons*. Final acceptance of the data by PDS will occur after liens have been cleared. The early deliveries of data to PDS, most particularly the Jupiter encounter data, will help to identify potential problems early in the mission, thus avoiding liens on the data that may require significant resources to correct in the final archive.

Table 3
Schedule of Key Mission Events and PDS Data Deliveries.

Event	*Relative Time*	*Nominal Date*
Launch (L)		1/2006
Cruise I		2006 through 2007
Jupiter Encounter		2-3/2007
Jupiter Closest Approach (JCA)		
End of Jupiter Downlink (EJD). • Cruise 1 instrument data • Jupiter Encounter data (all instruments)	JCA + 120 Days	7/2007
PDS Data Delivery (J1). • Cruise 1 instrument data, CODMAC Level 2 • Jupiter Encounter data (all instruments), CODMAC Level 2	EJD + 3 Months	9/2007
PDS Data Delivery (J2). • Cruise 1 instrument data, archival CODMAC Level 3 (4)[1] • Jupiter Encounter data (all instruments), archival CODMAC Level 3 (4) • Jupiter Encounter data (all instruments), CODMAC Level 5	EJD + 12 Months	5/2008
Cruise II	JCA + 121 Days through PCA Š 151 Days	
Cruise II Checkout #1		2008
Cruise II Checkout #2		2009
Cruise II Checkout #3		2010
Cruise II Checkout #4		2011
End of Cruise II Downlink #1 (ECD1)		
PDS Data Delivery. • Annual Checkout instrument data from Checkouts #1 through #4	ECD1 + 6 Months	
Cruise II Checkout #5		2012
Cruise II Checkout #6		2013
Cruise II Checkout #7		2014
End of Cruise II Downlink #2 (ECD2)		
PDS Data Delivery. • Annual Checkout instrument data from Checkouts #5 through #8	ECD2 + 6 Months	
Pluto / Charon Encounter	PCA - 150 Days through PCA + 14 Days	2-8/2015
Pluto Closest Approach (PCA)		7/2015
End of Contingency Data Downlink (ECDD)	PCA + 1 Day	7/2015
End of Quick Look Data Downlink	PCA + 10 Days	7/2015
End of Group 1 Data Downlink (EG1D)	PCA + 60 Days	9/2015
PDS Data Delivery (P1). • Contingency and Group 1 Š CODMAC Level 2 • Groups 2 and 3 Š NONE	PCA + 4 Months = EG1D + 2 Months = ECDD + 4 Months	11/2015
End of Pluto / Charon Downlink (EPD)	PCA + 10 Months EPD + 12 Months = EG1D + 20 Months = ECDD + 22 Months	5/2016
PDS Data Delivery (P2). • Contingency and Group 1 Š archival CODMAC Level 3 (4) • Groups 2 and 3 Š CODMAC Level 2	EPD + 4 Months = EG1D + 12 Months = ECDD + 14 Months	8/2016
PDS Data Delivery (P3). • Contingency and Group 1 Š CODMAC Level 5 • Groups 2 and 3 Š archival CODMAC Level 3(4), CODMAC Level 5 THIS IS THE FINAL PDS DELIVERY FOR THE NOMINAL MISSION.	EPD + 12 Months = EG1D + 20 Months = ECDD + 22 Months	3/2017

[1] It is expected that calibrated instrument data will generally correspond to CODMAC Level 3. If a calibration algorithm requires irreversible transformation of the data, however, the resulting data products will correspond to CODMAC Level 4.

7. *NEW HORIZONS* DATA RELEASE POLICY

There are no proprietary data rights for the *New Horizons* mission. Selected uncalibrated (CODMAC Level 2) data, particularly image data, will be publicly released by the *New Horizons* project over the Internet in close to real time. The full *New Horizons* Project Data Policy is given in Appendix D.

Fully reduced, calibrated and corrected data products (CODMAC Level 3 or 4, and CODMAC Level 5) will be produced under the direction of the Instruments Teams and Science Theme Teams for delivery to PDS per the schedule given in Section 6. The PI and Science Theme Team Leaders are responsible for coordinating all *New Horizons* 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 - EXAMPLE NEW HORIZONS SCIENCE DATA PRODUCTS

Example data products proposed by the *New Horizons* Instrument and Science Theme Teams for archiving by the PDS.

MVIC (RALPH)
Validated raw images in PDS format with ancillary information.
Complete pre-flight calibration files with documentation.
Complete in-flight calibration files with documentation.
Final calibration files, calibration algorithms, and optimum parameters.
Image mosaics:
- Global monochromatic maps.
- Global color maps.
- Regional high-resolution maps.
- Composition (e.g., methane) maps.

Mission history file (an observing log, with names and objectives of sequences, anomalies).
Support data:
- Updated pointing (all images).
- Improved rotational elements.
- Control point networks.
- Shape models.
- Grid overlays for selected images.
- Regional stereo maps (digital elevation models).
- Cloud & haze maps.
- Global digital image mosaic (basemap).

LEISA (RALPH)
Validated raw spectral images, in PDS format, with ancillary information.
Complete pre-flight calibration files with documentation.
Complete in-flight calibration files with documentation.
Final calibration files, calibration algorithms, and optimum parameters.
Calibrated spectral image cubes, archived as sequences of individual spectral images.
Individual calibrated spectral images in PDS format with ancillary information.
Image mosaics.
Spectral maps.
Composition maps.
Surface temperature maps.
Mission history file (observing log).

ALICE
Validated raw spectra, in PDS format, with ancillary information.
Complete pre-flight calibration files with documentation.
Complete in-flight calibration files with documentation.
Final calibration files, calibration algorithms, and optimum parameters.
Individual calibrated airglow and occultation spectra in PDS format with ancillary information.
Wavelength-dependent solar and stellar atmospheric occultation profiles.
Upper atmospheric temperature and pressure profiles, composition profiles for selected species, and (if present) haze/cloud profiles.

Mission history file (observing log).

REX
Validated raw data in PDS format with ancillary information.
Complete pre-flight calibration files with documentation.
Complete in-flight calibration files with documentation.
Final calibration files, calibration algorithms, and optimum parameters.
Time series of receiver output voltage and intensities.
Atmospheric refractivity profiles.
Atmospheric temperature and pressure profiles.
Radiometric tracking data (Doppler data).
GM values and radii for target bodies.
Surface temperatures from radiometry.
Ionospheric profiles.
Mission history file (observing log).

SWAP
Validated raw data in PDS format with ancillary information.
Complete pre-flight calibration files with documentation.
Complete in-flight calibration files with documentation.
Final calibration files, calibration algorithms, and optimum parameters.
Time series of counts per channel with ancillary information.
Time dependent particle intensities versus energy and direction.
Solar wind density, velocity, and ion temperature along *New Horizons* trajectory.
Mission history file (observing log).

PEPSSI
Validated raw data in PDS format with ancillary information.
Complete pre-flight calibration files with documentation.
Complete in-flight calibration files with documentation.
Final calibration files, calibration algorithms, and optimum parameters.
Time series of counts per channel with ancillary information.
Time dependent particle intensities versus energy and direction.
Energetic particle composition along *New Horizons* trajectory.
Energetic particle moments (pressure, energy density) along *New Horizons* trajectory.
Mission history file (observing log).

LORRI
Validated raw images in PDS format with ancillary information.
Complete pre-flight calibration files with documentation.
Complete in-flight calibration files with documentation.
Final calibration files, calibration algorithms, and optimum parameters.
Image mosaics:
- Global monochrome maps.
- Regional high-resolution surface and cloud/haze maps.

Mission history file (an observing log, with names and objectives of sequences, anomalies).
Support data:
- Updated pointing (all images).

Improved rotational elements.
Control point networks.
Shape models.
Grid overlays for selected images.
Regional stereo maps (digital elevation models).
Global digital image mosaic (basemap).

SDC (An Education/Public instrument which will deliver an archive on a best-effort basis.)
Validated raw data in PDS format with ancillary information.
Complete pre-flight calibration files with documentation.
Complete in-flight calibration files with documentation.
Final calibration files, calibration algorithms, and optimum parameters.
Time series of particle counts along the mission trajectory.
Particle size distribution along the mission trajectory.
Dust density profile across the entire mission.
Mission history file (observing log).

SPICE
SCLK Time calibration kernels.
Predict navigation kernels.
Predict spacecraft attitude kernels.
After-the-fact navigation kernels.
After-the-fact spacecraft attitude kernels.
Frame kernels.
Instrument kernels.
Leapsecond kernel.

AUXILIARY ARCHIVE COMPONENTS

Instrument and data set descriptions to be incorporated into templates according to PDS guidelines.
Particles and fields context model vector maps.

Appendix B - GLOSSARY OF TERMS AND ACRONYMS

TERMS

Catalog object	-	A PDS-required file formally documenting the details of a mission, spacecraft, instrument, or data set.
Label	-	An attached or detached header which formally describes the structure and content of a data file.
Lien	-	An action recommended by reviewers or PDS personnel to correct the archive.
Template	-	Same as a catalog object
Volume	-	A single CD-ROM or other volume of a storage medium.

NAMES AND ACRONYMS

Alice	-	The *New Horizons* ultraviolet mapping spectrometer.
AID	-	PDS **A**rchive **I**nterface **D**ocument.
APL	-	**A**pplied **P**hysics **L**aboratory, at the Johns Hopkins University.
ATM	-	**A**tmospheric **S**tudies **T**eam.
C&DH	-	**C**ommand and **D**ata **H**andling system for the *New Horizons* spacecraft.
CCSDS	-	**C**onsultative **C**ommittee for **S**pace **D**ata **S**ystems.
CODMAC	-	**C**ommittee **O**n **D**ata **M**anagement **A**nd **C**omputation. CODMAC standard data level definitions are required for data products archived to the PDS.
DPW	-	PDS **D**ata **P**reparation **W**orkbook.
DSN	-	**D**eep **S**pace **N**etwork.
GGI	-	**G**eology and **G**eophysics **I**maging team.
GSE	-	**G**round **S**upport **E**quipment.
JCA	-	Date of **J**upiter **c**losest **a**pproach.
JPL	-	**J**et **P**ropulsion **L**aboratory.
KBO	-	**K**uiper **B**elt **O**bject.
LEISA	-	**L**inear **E**talon **I**maging **S**pectral **A**rray. This is the IR wavelength detector of the Ralph instrument.
LORRI	-	**Lo**ng **R**ange **R**econnaissance **I**mager. The *New Horizons* long focal length imager.
MOC	-	**M**ission **O**perations **C**enter
MVIC	-	**M**ultispectral **V**isible **I**maging **C**amera. This is the visible wavelength detector of the Ralph instrument.
NAIF	-	**N**avigation and **A**ncillary **I**nformation **F**acility, a node of PDS.
NASCOM	-	**NAS**A **Com**munications.
NEAR	-	**N**ear **E**arth **A**steroid **R**endezvous.
NH Level	-	*New Horizons* **L**evel. Indicates use of the mission legacy data level definitions.
NSSDC	-	**N**ational **S**pace **S**cience **D**ata **C**enter.
P&P	-	**P**articles and **P**lasmas team.
PCA	-	Date of **P**luto **c**losest **a**pproach.
PDS	-	The **P**lanetary **D**ata **S**ystem.

PEPSSI	-	**P**luto **E**nergetic **P**article **S**pectrometer **S**cience **I**nvestigation. A medium energy particle spectrometer.
PPI	-	**P**lanetary **P**lasma **I**nteractions, a discipline node of the PDS.
Ralph	-	The combined instrument consisting of the MVIC and LEISA detectors along with their common electronics, housing, optical elements, radiator, thermal control system, and mounting flexure system.
REX	-	The **R**adio Science **Ex**periment, a *New Horizons* experiment package.
SBN	-	**S**mall **B**odies **N**ode. The PDS lead node for *New Horizons*.
SCM	-	**S**urface **C**omposition **M**apping team.
SDC	-	**S**tudent **D**ust **C**ounter. The interplanetary dust distribution mapping instrument.
SOC	-	**S**cience **O**perations **C**enter.
SPICE	-	**S**pacecraft, **P**lanet, **I**nstrument, **C**-matrix, **E**vents. The NAIF ancillary data system (navigation and geometry).
SR	-	The PDS **S**tandards **R**eference.
STT	-	**S**cience **T**heme **T**eam.
SWAP	-	**S**olar **W**ind **A**round **P**luto. The *New Horizons* solar wind and low energy plasma instrument.

Appendix C - NEW HORIZONS AND CODMAC DATA LEVEL DEFINITIONS[1]

NH (Legacy)	CODMAC	Description
0	1	The raw telemetry data as received at the ground receiving station or ground test GSE, organized by contacts or ground test.
0a		The telemetry data as produced by the C&DH system on the spacecraft and passed to the telemetry subsystem. NASCOM headers and trailers have been separated. NH Level 0a contains transfer frame packets organized by contacts or ground tests.
0b		The transfer frame packets plus radiometric tracking data, all organized by contacts or ground test.
1		NH Level 0b data that have been cleaned and merged, time ordered, and in packet format. Cleaned and merged means that duplicate data have been deleted, missing packets are padded out, and the data are organized by days. The actual format of these data is the same as NH Level 0b. This is the level that should be passed to the instrument GSE's for their processing.
1a		The NH Level 1 data that have been separated by instrument.
1b	2	Fully decommutated raw data. The NH Level 1a data that have been sorted by instrument data types and instrument modes. Data are in scientifically useful form, e.g. as images or individual spectra. These data are still uncalibrated.
2	3 (4)	Provisional and archival calibrated data. NH Level 1b with calibration and corrections applied to yield data in scientific units. Note: The data at this level will generally correspond to CODMAC Level 3. If a calibration algorithm involves irreversible transformations of the data, however, the data products will correspond to CODMAC Level 4.
3	5	Derived data products. Higher level derived data products developed for specific scientific investigations.

[1]CODMAC data levels for PDS archives are defined in the *Planetary Data System Standards Reference* (JPL D-7669, Part 2), p. 6-6 (version of August 1, 2003).

Appendix D - NEW HORIZONS PROJECT DATA POLICY

This is a summary of the data analysis and release policies for the New Horizons Project. It is meant to cover the pre-flight, post-launch, and data analysis activities of the New Horizons Mission Science Team and associated scientists. The New Horizons Data Policy is based upon a set of four general principles, referred to below as ground rules that apply to planetary missions funded by NASA. To implement these principles, guidelines are adopted as given below. These guidelines are applicable to the period prior to the submission of mission data to the Planetary Data System, after which the data are freely and publicly available through PDS.

Ground Rules

- Selected uncalibrated data, including image data, will be publicly released over the INTERNET in close to real time.
- Fully reduced, calibrated and corrected data products will be published and forwarded to the Planetary Data System as soon as they have been generated and validated.
- The Project strongly encourages shared data analyses, under the direction of the teams whose data are being used, among members of different instrument teams.
- The PI, Instrument Teams Leaders, and Science Theme Team Leaders are responsible for coordinating all scientific investigations involving the use of data from their respective instruments.

Guidelines

- In the interest of a systematic and orderly data analysis, the PI must approve of all scientific investigations involving the use of data from the mission instruments.
- Likewise, the PI must approve of all plans to release or to publish calibrated data. In this context, 'to publish' includes not only journal articles but also abstracts and presentations.