Passive Seismic Experiments from the Apollo Lunar Surface Experiments Package (ALSEP) and the Early Apollo Scientific Experiments Package (EASEP)

PDS Archive

Software Interface Specification

Rev. 1.0

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1 Introduction

This software interface specification (SIS) describes the format and content of data acquired by the Apollo Passive Seismic Experiments for the Planetary Data System (PDS) data archive. It includes descriptions of the data products and associated metadata, and the archive format, content, and generation pipeline.

1.1 Document Change Log

Table 1: Document Change Log

Version	Change	Date	Affected portion
0.1	Initial draft	Oct. 15, 2021	All
0.2	Additional sections in response to PDS review.	Mar. 22, 2022	1 Introduction 2.3 Applicable Documents 2.6.1 Data Resources 2.6.3 Detectors 2.6.7 Metadata 3.1 Data Product Overview 3.2.1 Data Processing Levels 3.3.2 Data Gaps 3.3.3 Start and End Times 3.3.6 Earlier Channel Naming Conventions 4.1.3.1Mini-SEED Data Files
0.3	Changed geocsv label	Jul. 17, 2022	B4 GeoCSV label
1.0	Released version	Sep. 20, 2022	2.3 Added link to Nunn et al., 2022 Appendix B Updated sample labels

1.2 TBD Items

Table 2 lists items that are not yet finalized.

Table 2: List of TBD items

Item	Section(s)	Page(s)
None.		

1.3 Abbreviations

Table 3: Abbreviations and Their Meanings

Abbreviation	Meaning
ALSEP	Apollo Lunar Surface Experiment Package

Abbreviation	Meaning
ASCII	American Standard Code for Information Interchange
ATT	Timing trace for mid-period and short-period seismometers
EASEP	Early Apollo Scientific Experiments Package
EDR	Experiment Data Record
GB	Gigabyte(s)
GEO	PDS Geosciences Node (Washington University, St. Louis, Missouri)
IM	Information Model
IRIS	Incorporated Research Institutions for Seismology
JPL	Jet Propulsion Laboratory (Pasadena, CA)
LID	Logical Identifier
LIDVID	Versioned Logical Identifier
MH1	Horizontal channel 1 of the mid-period seismometer
MH2	Horizontal channel 2 of the mid-period seismometer
MHZ	Vertical channel of the mid-period seismometer
MP	Mid Period
NASA	National Aeronautics and Space Administration
NSSDCA	National Space Science Data Coordinated Archive (GSFC)
PDS	Planetary Data System
PDS4	Planetary Data System Version 4
PSE	Passive Seismic Experiment
SEED	Standard for the Exchange of Earthquake Data
SIS	Software Interface Specification
SHZ	Vertical channel of the short-period seismometer
SP	Short Period
TBD	To Be Determined
URN	Uniform Resource Name
XML	eXtensible Markup Language

1.4 Glossary

Many of these definitions are taken from Appendix A of the PDS4 Concepts Document, https://pds.nasa.gov/datastandards/documents/concepts/. The reader is referred to that document for more information.

Archive – A place in which public records or historical documents are preserved; also the material preserved – often used in plural. The term may be capitalized when referring to all of PDS holdings – the PDS Archive.

Basic Product – The simplest product in PDS4; one or more data objects (and their description objects), which constitute (typically) a single observation, document, etc. The only PDS4 products that are *not* basic products are collection and bundle products.

Bundle Product – A list of related collections. For example, a bundle could list a collection of raw data obtained by an experiment during its mission lifetime, a collection of the calibration products associated with the experiment, and a collection of all documentation relevant to the first two collections.

Class – The set of attributes (including a name and identifier) which describes an item defined in the PDS Information Model. A class is generic – a template from which individual items may be constructed.

Collection Product – A list of closely related basic products of a single type (e.g. observational data, browse, documents, etc.). A collection is itself a product (because it is simply a list, with its label), but it is not a *basic* product.

Data Object – A generic term for an object that is described by a description object. Data objects include both digital and non-digital objects.

Description Object – An object that describes another object. As appropriate, it will have structural and descriptive components. In PDS4 a 'description object' is a digital object – a string of bits with a predefined structure.

Digital Object – An object which consists of real electronically stored (digital) data.

Identifier – A unique character string by which a product, object, or other entity may be identified and located. Identifiers can be global, in which case they are unique across all of PDS (and its federation partners). A local identifier must be unique within a label.

Label – The aggregation of one or more description objects such that the aggregation describes a single PDS product. In the PDS4 implementation, labels are constructed using XML.

Logical Identifier (**LID**) – An identifier which identifies the set of all versions of a product.

Versioned Logical Identifier (LIDVID) – The concatenation of a logical identifier with a version identifier, providing a unique identifier for each version of product.

Manifest - A list of contents.

Metadata – Data about data – for example, a 'description object' contains information (metadata) about an 'object.'

Object – A single instance of a class defined in the PDS Information Model.

PDS Information Model – The set of rules governing the structure and content of PDS metadata. While the Information Model (IM) has been implemented in XML for PDS4, the model itself is implementation independent.

Product – One or more tagged objects (digital, non-digital, or both) grouped together and having a single PDS-unique identifier. In the PDS4 implementation, the descriptions are combined into a single XML label. Although it may be possible to locate individual objects within PDS (and to find specific bit strings within digital objects), PDS4 defines 'products' to be the smallest granular unit of addressable data within its complete holdings.

Tagged Object – An entity categorized by the PDS Information Model, and described by a PDS label.

Registry – A data base that provides services for sharing content and metadata.

Repository – A place, room, or container where something is deposited or stored (often for safety).

XML – eXtensible Markup Language.

XML schema – The definition of an XML document, specifying required and optional XML elements, their order, and parent-child relationships.

2 Overview

2.1 Purpose and Scope

The purpose of this SIS (Software Interface Specification) document is to provide users of the Apollo Passive Seismic Experiment (PSE) archive with a detailed description of the data products and how they were generated, along with a description of the PDS4 archive bundle, the structure in which the data products, documentation, and supporting material are stored. This SIS covers raw data products generated by the PSE that are archived in the Planetary Data System (PDS). In particular, these products consist of the seismic data downlinked from the PSE instruments and stored in SEED (Standard for the Exchange of Earthquake Data) format, and the same data converted to ASCII text tables in a PDS4-compatible format.

2.2 SIS Contents

This SIS describes how the PSE instruments acquired data, and how the data were processed, formatted, labeled, and uniquely identified. The document discusses standards used in generating the data products and software that may be used to access the products. The data structure and organization are described in sufficient detail to enable a user to read and understand the data. Appendices include a description of the file naming conventions used in the PSE archive, and a list of cognizant persons involved in generating the archive.

2.3 Applicable Documents

[1] Planetary Data System Standards Reference, Version 1.16.0, April 21, 2021.
[2] Planetary Science Data Dictionary Document, Version 1.16.0.0, April 23, 2021.
[3] Planetary Data System (PDS) PDS4 Information Model Specification, Version 1.16.0.0, April 23, 2021.
[4] Data Providers' Handbook: Archiving Guide to the PDS4 Data Standards, Version 1.16.0, April 21, 2021.
[5] SEED Reference Manual, SEED Format Version 2.4, International Federation of Digital Seismograph Networks, Incorporated Research Institutions for Seismology, United States Geological Survey, August 2012. http://www.fdsn.org/seed_manual/SEEDManual_V2.4.pdf
[6] GeoCSV – Tabular Text Formatting for Geoscience Data, version 2.0.4, July 21, 2015, Incorporated Research Institutions for Seismology (IRIS), http://geows.ds.iris.edu/documents/GeoCSV.pdf.
[7] FDSN StationXML Schema, International Federation of Digital Seismograph Networks (FDSN), version 1.0, https://www.fdsn.org/xml/station.
[8] Nunn, C., Nakamura, Y., Kedar, S., Panning, M. P., 2022, A New Archive of Apollo's Lunar Seismic Data, Planet. Sci. J., **3** 219, https://iopscience.iop.org/article/10.3847/PSJ/ac87af.
[9] Electronic Supplement of [8], https://github.com/cerinunn/pdart
[10] Nunn, C., Garcia, R.F., Nakamura, Y., Marusiak, A.G., Kawamura, T., Sun, D., Margerin, L., Weber, R., Drilleau, M., Wieczorek, M.A., Khan, A., Rivoldini, A., Lognonné, P., Zhu, P., 2020. Lunar Seismology: A Data and Instrumentation Review. Space Sci Rev 216, 89. https://doi.org/10.1007/s11214-020-00709-3
[11] Electronic Supplement of [10], https://doi.org/10.5281/zenodo.1463224

[12] Wagner, R.V., Nelson, D.M., Plescia, J.B., Robinson, M.S., Speyerer, E.J., Mazarico, E., 2017. Coordinates of anthropogenic features on the Moon. Icarus, Lunar Reconnaissance Orbiter - Part II 283, 92–103. https://doi.org/10.1016/j.icarus.2016.05.011
[13] Latham, G., Ewing, M., Press, F., Sutton, G., 1969. The Apollo Passive Seismic Experiment. Science 165, 241–250.
[14] Weber, Renee C. (2019), Apollo Passive Seismic Experiment Expanded Event Catalog Bundle (Version 1.0), PDS Planetary Geosciences Node (GEO), https://doi.org/10.17189/1520573.
[15] McLaughlin, S.A. (2017), Apollo Documents Bundle (Version 1.0), PDS Planetary Geosciences Node (GEO), https://doi.org/10.17189/1518455.
[16] Getting Started Jupyter Notebook (electronic supplement of [8]), https://github.com/cerinunn/pdart/blob/master/getting_started.ipynb

The PDS4 Documents [1] through [3] are subject to revision. The most recent versions may be found at pds.nasa.gov. The PSE PDS4 products specified in this SIS have been designed based on the versions current at the time, which are those listed above.

2.4 Audience

This document serves both as a Data Product SIS and an Archive SIS. It describes the format and content of PSE data products in detail, and the structure and content of the archive in which the data products, documentation, and supporting material are stored. This SIS is intended to be used by data users, particularly seismologists, wishing to understand the format and content of the archive.

2.5 Apollo Missions

Passive seismic experiments were deployed with Apollo 11 (1969), Apollo 12 (1969), Apollo 14 (1971), Apollo 15 (1971) and Apollo 16 (1972) [10]. Apollo 11 returned seismic data for around twenty days. The remaining stations operated nearly continuously from their installation until September 1977, forming a small lunar seismic network. The passive experiment on Apollo 11 was included with the Early Apollo Surface Experiment Package, and the passive experiments on the remaining stations were part of the Apollo Lunar Surface Experiments Package.

2.6 PSE Instrument Description

Each of the Apollo Passive Seismic Experiments included two sets of instruments: a mid-period instrument and a short-period instrument (although the short-period instrument did not function at Apollo 12).

2.6.1 Data Resources

Before using the data, data users should familiarize themselves with the paper [8] which describes how the data were archived. They should also read the Getting Started page on the github site [9,16], https://github.com/cerinunn/pdart/blob/master/getting_started.ipynb.

2.6.2 Science Objectives

The PSE experiments were designed to detect naturally occurring seismic events on the surface of the Moon [13]. The objectives included measuring the rate of meteoroid impacts and determining whether moonquakes occurred. Using either external or internal sources, another objective was to determine the structure of the lunar crust, and potentially, the deeper structure.

2.6.3 Detectors

The PSE consisted of one three-axis mid-period seismometer (MP) and one vertical component short-period seismometer (SP) to measure ground motion generated by seismic waves traveling through the interior.

The mid-period seismometer made measurements proportional to displacement, unlike most modern seismometers covering these frequencies, which make measurements proportional to velocity. The nominal sampling interval was 0.1509434 s [8]. The instrument could operate in one of two modes: peaked-response or flat-response. In peaked-response mode the transfer function was sharply peaked at 2.2 s [8]. The engineers also designed a flat mode to be sensitive to a broader range of frequencies, and used a positive feedback filter in the circuit. In the flat-response mode the seismometers had natural periods of 15 s and could detect ground motions as small as 0.3 nm over the frequency range from 0.1 Hz to 1 Hz [8]. Unfortunately, the flat mode was not very stable, and the seismometers were mainly commanded to operate in peaked mode [10]. The short-period sensor was a vertical sensor with a standard coil-magnet velocity transducer. It had a displacement response peaked at approximately 8 Hz and the nominal sampling interval was 0.0188679s [8].

2.6.4 Measured Parameters

The data were recorded with digital units (DU), with values from 0 to 1023 [10]. The values lay somewhere in the middle of the range when the seismometer was at rest, although the rest position varies with the time of lunar day. One digital unit corresponded to ~0.08 nm of ground displacement in peaked-response mode and ~0.3 nm in flat-response mode at 0.45 Hz [10]. Users can transform the data into displacement, velocity, or acceleration with the provided SEED metadata files.

2.6.5 Operational Modes

The engineers controlled the gain from Earth, and were able to cycle through the options (from maximum gain, -10 dB, -20 dB, -30 dB and back to maximum). The timing of the gain changes is included in the Electronic Supplement of [8].
(https://github.com/cerinunn/pdart/tree/master/Electronic_Supplement/CalibrationFiles).

2.6.6 Calibration

The PSE employed standard seismological calibration techniques throughout surface operations. A step of current equivalent to a known step of ground acceleration was applied to the coil for each of the seismometer components. The timing of the calibration pulses is included in [9] (https://github.com/cerinunn/pdart/tree/master/Electronic_Supplement/CalibrationFiles). Reference [9] shows an example calibration pulse:
https://github.com/cerinunn/pdart/blob/master/Electronic_Supplement/files/Calibration_pulse.png

2.6.7 Metadata

The metadata (or dataless files) were originally produced by researchers at IPGP, but have been modified to use our naming conventions and updated coordinates for the stations. Seismometer responses are included, but are only the nominal responses. Some differences may be observed between the nominal and actual responses.

2.6.8 Other Resources

Reference [11] (the electronic supplement of [10]) contains a collection of resources for lunar seismology which may be useful to this audience, including S1 - Location Parameters, S2 - Deep Moonquake Stacks, S3 - Lunar Catalog from Various Sources, S4 - Extensive Lunar Catalog, S5 - Attenuation Parameters and S9 - Artificial Impacts. Reference [14] contains a catalog of lunar seismic events.

3 PSE Raw Data Products

3.1 Data Product Overview

The PSE archive contains data from the mid-period sensors (MH1, MH2 and MHZ), the short-period seismometer (SHZ) and the timing trace (ATT). Transmission terminated in September 1977. Data has been converted to both SEED format files and ASCII tables (GeoCSV) for analysis and archiving.

3.2 Data Processing

This section describes the processing of PSE data products, their structure and organization, and their labeling.

3.2.1 Data Processing Levels

Data processing levels mentioned in this SIS refer to PDS4 processing levels. Table 4 provides a description of these levels.

Table 4: Data Processing Level Definitions

PDS4 processing level	PDS4 processing level description
Raw	Original data from an experiment. If compression, reformatting, packetization, or other translation has been applied to facilitate data transmission or storage, those processes are reversed so that the archived data are in a PDS approved archive format. Often called EDRs (Experimental Data Records).
Partially Processed	Data that have been processed beyond the raw stage but which have not yet reached calibrated status. These and more highly processed products are often called RDRs (Reduced Data Records).
Calibrated	Data converted to physical units, which makes values independent of the experiment.
Derived	Results that have been distilled from one or more calibrated data products (for example, maps, gravity or magnetic fields, or ring particle size distributions). Supplementary data, such as calibration tables or tables of viewing geometry, used to interpret observational data should also be classified as 'derived' data if not easily matched to one of the other three categories.

Apollo PSE data products described in this SIS are raw data. Rather than creating calibrated data products by transforming the seismic data to physical units, the PSE Team uses the SEED standard to provide the complete transfer function enabling that transformation. Should better calibration information become available, the PSE team will revise the SEED dataless files.

3.2.2 Data Product Generation

The PSE team produced the SEED files from copies of the seismic data preserved from the Apollo mission. The steps taken to process the data for the SEED archive and the work

previously completed to downlink, store and preserve the data is described in [8]. The archive contains 53 GB of Mini-SEED files.

3.2.3 Data Flow

The PSE Team generated the Mini-SEED files and the metadata. They also generated PDS4 labels for the data products, assembled the PSE raw data archive bundle and delivered it to the PDS Geosciences Node. The full bundle consists of A) PSE data in Mini-SEED format, paired with a dataless SEED metadata file, B) the same data in GeoCSV format, paired with a StationXML metadata file, and C) the PDS4 labels for both. The Geosciences Node has validated the delivery and will make it available online for public use.

3.2.4 Data Delivery Schedule

The mission is complete, and therefore no future deliveries are anticipated.

3.3 Standards Used in Generating Data Products

PSE products and labels comply with Planetary Data System standards, including the PDS4 data model, as specified in applicable documents [1], [2] and [3].

3.3.1 Time Standards

The data traces are arranged with nominal sampling intervals of 0.1509433962 s for MH1, MH2 and MHZ and 0.01886792453 s for SHZ. The actual sampling rates can be estimated from the timing trace ATT. Data were transmitted from the Moon in frames. The ATT trace contains the timestamp for the head of the frame. The timestamp represents the time that the signal was received on Earth. Since the sample time uses the nominal sampling interval, there is a small divergence between the sampling time and the original timestamp. This can accumulate to a few seconds (positive or negative) after 24 hours.

The data were recorded in real time. Therefore, in theory, the data from each Apollo station should be synchronized with the other stations. However, in practice, there may have been some issues in recording the timestamp for each individual station (each station was recorded separately, so if there was difficulty recording the time for one station, then the station may be out of sync with the other stations. We correct for these errors where possible (see [8]), but correcting time periods when the timestamp was not being read correctly.

The PSE team do not correct for the 1.2–1.4 s delay time when transmitting from the Moon to Earth. Additionally, the team do not correct for the apparent variations in sampling rate which are caused by changes in the orbital parameters of the Moon-Earth system, such as by the rotation of the Earth, the libration of the Moon or changes in Moon-Earth distance.

3.3.2 Data Gaps

Data gaps are represented by -1 (an integer) on the MHZ, MH1, MH2 and SHZ trace and -1.0 (a float) on the ATT trace. The Getting Started page [16] has example code to read in, process and plot the data without the gaps.

The original data were transmitted with 3-4 missing samples (see [8] for more details) every 32 samples. This number of missing samples made the miniSEED files very large, which is why we replaced the missing samples with constant values. Individual missing samples are less common

on the other traces, but we replaced the missing samples on the other traces to be consistent with the SHZ trace.

3.3.3 Start and End Times

Traces are split into Earth days. The first timestamp will be the first valid timestamp after midnight. The timestamps have a sampling interval of ~0.6038 s, and so typically the first valid timestamp falls in the first 0.6038 s. If the data were not valid, the first timestamp will be later. As described above, there is a small divergence of a few seconds between the sampling time and the original timestamp. Therefore, the sampling time may end a few seconds before or after midnight. In this archive, sampling times which overrun past midnight (but the original timestamps are in the current day) are included in the trace for the current day.

3.3.4 Coordinate Systems

The coordinates of the stations on the Moon were redefined using high-resolution images from the Lunar Reconnaissance Orbiter Camera Narrow Angle Camera [12], and are provided in the DE421 Mean Earth / Rotation Axis Reference Frame. The orientation of the MH1 and MH2 sensors were estimated using sundials.

3.3.5 Data Storage Conventions

Each PSE raw data product is stored in two formats, Mini-SEED and ASCII (GeoCSV). The data were converted to Mini-SEED format, an international standard for storing seismic data [5]. They are also converted to PDS4-compliant ASCII tables (GeoCSV) to meet PDS4 archiving requirements. The PSE archive includes both formats for each raw data product. The content is the same in both formats. See section 5.1 for details on both formats.

3.3.6 Earlier Channel Naming Conventions

We use the modern naming conventions for the mid-period instruments (MH1, MH2, MHZ) and short-period instrument (SHZ). We use MH1 and MH2 because not all of the stations point north and east (see the metadata for the coordinates). Most earlier papers refer to the instruments and long period and short period, with the channel names LPX, LPY, LPZ and SHZ. The names can be considered as directly equivalent.

3.4 Applicable Software

PSE Mini-SEED data and either Dataless SEED or StationXML may be read using the using the ObsPy Python environment (https://github.com/obspy/obspy/wiki). If required, Mini-SEED files may be transformed to other formats including ASCII, SAC and SEGY.

Alternatively Mini-SEED files may be transformed to SAC files with mseed2sac (http://ds.iris.edu/pub/programs/converters/) and used within SAC (https://seiscode.iris.washington.edu/projects/sac).
Another option to read Mini-SEED files is Rdseed (https://github.com/iris-edu-legacy/rdseed), which can also convert Mini-SEED data to ASCII tables, which may be read using text editors and spreadsheet programs, as well as MATLAB (https://www.mathworks.com/matlabcentral/fileexchange/28803-rdmseed-and-mkmseed--read-and-write-miniseed-files).

3.5 Backups and duplicates

The Geosciences Node keeps two copies of each archive product. One copy is the primary online archive copy, another is a backup copy. Once the archive products are fully validated and approved for inclusion in the archive, a third copy of the archive is sent to the National Space Science Data Coordinated Archive (NSSDCA) for long-term preservation in a NASA-approved deep-storage facility. The Geosciences Node will maintain additional copies of the archive products off-site as deemed necessary.

4 PSE Archive Organization, Identifiers and Naming Conventions

This section describes the basic organization of the PSE raw data archive under the PDS4 Information Model (IM) (Applicable Documents [1] and [3]), including the naming conventions used for the bundle, collection, and product unique identifiers. The formation of logical identifiers is described in section 4.1. Bundles, collections and products are defined and given identifiers in section 4.2. In short, a group of related products forms a collection, and a group of related collections forms a bundle.

4.1 Logical Identifiers

Every product in PDS is assigned an identifier that allows it to be uniquely identified across the system. This identifier is referred to as a Logical Identifier or LID. Each product also has a Version Identifier (VID) that allows different versions of a specific product to be referenced uniquely. A product's LID and VID are defined as separate attributes in the product label. For convenience they may be combined in a single string called a LIDVID, with two colons between the LID and the VID. If a particular version of a product is desired, the LIDVID should be used; otherwise, the LID alone should be used with the understanding that it refers to the latest version of the product.

LIDs and VIDs are assigned by PDS and are formed according to the conventions described in the following sections. The uniqueness of a product's LIDVID may be verified using the PDS Registry and Harvest tools. More information on LIDs and VIDs may be found in section 6d of the PDS Standards Reference [1] and in chapter 5 of the Data Providers' Handbook [4].

4.1.1 LID Formation

LIDs take the form of a Uniform Resource Name (URN). LIDs are restricted to ASCII lower case letters, digits, dash, underscore, and period. Colons are also used, but only to separate prescribed components of the LID. Within one of these prescribed components dash, underscore, or period are used as separators. LIDs are limited in length to 255 characters.
Apollo PSE LIDs are formed according to the following conventions:

- Bundle LIDs are formed by appending a bundle specific ID to the PDS base ID:

  urn:nasa:pds:<bundle ID>
  Example: urn:nasa:pds:apollo_pse

  The bundle ID must be unique across all bundles archived with the PDS.
- Collection LIDs are formed by appending a collection specific ID to the collection's parent bundle LID:

  urn:nasa:pds:<bundle ID>:<collection ID>
  Example: urn:nasa:pds:apollo_pse:data_seed

  The collection ID must be unique across the bundle. Collection IDs correspond to the collection type (e.g. "browse", "data", "document", etc.). Additional descriptive information may be appended to the collection type (e.g. "data-raw", "data-calibrated", etc.) to insure that multiple collections of the same type within a single bundle have unique LIDs.
- Basic product LIDs are formed by appending a product-specific ID to the product's collection LID:

  urn:nasa:pds:<bundle ID>:<collection ID>:<product ID>

Example: urn:nasa:pds:apollo_pse:data_seed:xa.s12.01.mhz.1976.061.0

The product ID must be unique across the collection. For PSE data products, the product LID is the same as the lowercase data file name without the extension.

4.1.2 VID Formation

Product Version IDs consist of major and minor components separated by a "." (M.n). Both components of the VID are integer values. The major component is initialized to a value of "1", and the minor component is initialized to a value of "0". The minor component resets to "0" when the major component is incremented. The PDS Standards Reference [1] specifies rules for incrementing major and minor components.

4.1.3 File Naming Conventions

4.1.3.1 Mini-SEED Data Files

For continuous science packets, one single file is created per UTC day for each Mini-SEED channel/location code pair.

The directory and filename convention for continuous data is:

directory name **data/<NETWORK>/continuous_waveform/<STATION>/<YEAR>/<JDAY>**

file name **NET.STA.[LOC].CHAN.YEAR.JDAY.REV.EXT**

where:

- NET is the Network ID,
- STA is the Station ID,
- LOC is the location ID,
- CHAN is the channel ID,
- YEAR is the earth year of the measurement,
- JDAY is the day-of-year (on Earth),
- REV is the revision of the file,
- EXT is file name extension (mseed for SEED format or csv for ASCII Table format).

An example file name is xa.s12.01.mhz.1976.061.0.mseed.

Channel codes (CHAN) specify one of MHZ, MH1, MH2 (mid-period sensor), SHZ (short-period sensor) or ATT (timing trace). Location codes are specified for the mid-period channels: '00' for peaked mode operation and '01' for flat mode operation.

The files include the following default fields for specifying the data encoding in Mini-SEED (described in [5]): 'byteorder', 'dataquality', 'encoding', 'filesize', 'number_of_records', 'record_length'. 'Dataquality' is set to 'D', 'The state of quality control of the data is indeterminate'.

4.1.3.2 Dataless SEED Header Files

A dataless SEED volume contains metadata only. These metadata are necessary to properly analyze the waveform data and include station coordinates, channel orientations, instrument response parameters, sample rate, timing information, etc. A dataless SEED volume is used in combination with a Mini-SEED volume. A dataless file, by definition, contains no "data", in the sense that no waveform data are included, only headers. Dataless SEED is the reference for the

metadata; it will be converted to stationXML (see section 4.1.4.3) using IRIS's stationXML to SEED converter[1].

Directory name: **data/<NET>/metadata/**
File name: **dataless.<NET>.<REV>.seed**
Example: **dataless.xa.0.seed**

4.1.3.3 ASCII Data Files in GeoCSV

The ASCII text equivalent of a Mini-SEED data file uses the GeoCSV convention for comma-separated value tables [6]. The file name is the same as the Mini-SEED file name, except that it ends in "a.csv" instead of ".mseed". The corresponding label file name ends in "a.xml".

4.1.3.4 ASCII Header Files in StationXML

The ASCII text equivalent of a dataless SEED header file, which contains metadata for Mini-SEED files, uses the StationXML format for seismic metadata [7]. StationXML files are written in eXtensible Markup Language (XML) and normally have the file name extension ".xml". As this conflicts with PDS4 labels, whose file names also end in ".xml", the StationXML file names use the extension ".sxml".
Directory name: **data/<NET>/metadata/**
File name: **stationxml.<NET>.<REV>.sxml**
Example: **stationxml.xa.0.sxml**

4.1.3.5 Examples

Examples of PSE data product file names are given in Table 5.

Table 5: Example File Names for PSE Data Products and Labels

Data File Type	Data File Name	Label File Name
Mini-SEED Continuous	xa.s12.01.mhz.1976.061.0.mseed	xa.s12.01.mhz.1976.061.0.xml
ASCII GeoCSV Continuous	xa.s12.01.mhz.1976.061.0.a.csv	xa.s12.01.mhz.1976.061.0.a.xml
Dataless SEED Header	dataless.xa.0.seed	dataless.xa.0.xml
ASCII StationXML Header	stationxml.xa.0.sxml	stationxml.xa.0.xml

4.2 Bundles

The highest level of organization for a PDS archive is the bundle. A bundle is a set of one or more related collections which may be of different types. A collection is a set of one or more related basic products which are all of the same type. Bundles and collections are logical structures, not necessarily tied to any physical directory structure or organization.

The complete PSE archive is organized into one bundle (Table 6).

Table 6: PSE Bundles

[1] https://seiscode.iris.washington.edu/projects/stationxml-converter

Bundle Logical Identifier	PDS4 Processing Level	Description
urn:nasa:pds:apollo_pse	Raw	PSE Data Bundle

4.3 Collections

Collections consist of basic products all of the same type. The PSE Bundle contains 3 primary collections: data_seed, data_table, and document. It also contains 6 secondary collections that are found in the Apollo Documents Bundle [15] and are not duplicated in the PSE Bundle. All 9 collections are listed in Table 7.

Table 7: Collections in the PSE Bundle

Collection Logical Identifier	Collection Type	Description	Member Status
urn:nasa:pds:apollo_pse:data_seed	SEED Data	Contains raw PSE measurements in SEED format.	Primary
urn:nasa:pds:apollo_pse:data_table	ASCII Table Data	Contains raw PSE measurements converted from SEED format to PDS4-compliant ASCII tables (GeoCSV).	Primary
urn:nasa:pds:apollo_pse:document	Apollo PSE Documents	Contains documents relevant to the PSE bundle, including the document you're reading.	Primary
urn:nasa:pds:apollodoc:a12doc	Apollo 12 Documents	Contains documents common to Apollo 12 PDS archives.	Secondary
urn:nasa:pds:apollodoc:a14doc	Apollo 14 Documents	Contains documents common to Apollo 14 PDS archives.	Secondary
urn:nasa:pds:apollodoc:a15doc	Apollo 15 Documents	Contains documents common to Apollo 15 PDS archives.	Secondary
urn:nasa:pds:apollodoc:a16doc	Apollo 16 Documents	Contains documents common to Apollo 16 PDS archives.	Secondary
urn:nasa:pds:apollodoc:a17doc	Apollo 17 Documents	Contains documents common to Apollo 17 PDS archives.	Secondary
urn:nasa:pds:apollodoc:commondoc	Apollo Common Documents	Contains documents common to multiple Apollo PDS archives.	Secondary

4.4 Products

A PSE data product consists of one digital object in one file, accompanied by a PDS label file. The PDS label provides identification and description information for the data file. As discussed above, the PDS label includes a Logical Identifier (LID) by which the product is uniquely identified throughout all PDS archives. Under the PDS4 standard, labels are XML-formatted ASCII files.

The PDS4 standard limits the formats of science data products to a small set of structures. Supplementary information for science products may be provided in a wider variety of formats. The SEED format does not fit any PDS4-compliant format for science data. Therefore, each PSE data product is archived in two formats: an ASCII table as the primary science data product (GeoCSV), and a SEED file as a supplementary product.

5 PSE Raw Data Product Formats

Data that comprise the PSE raw data archive are formatted in accordance with PDS specifications (see Applicable Documents [1], [2] and [3]). This section provides details on the formats used for each of the products included in the archive.

5.1 Data Product Formats

Each PSE raw data product is stored in two formats, SEED and ASCII text (GeoCSV). Ceri Nunn processed the data into SEED format and converted it to PDS-compliant ASCII tables (GeoCSV) using the mseed2ascii code provided by IRIS. Both versions are included in the archive.

5.1.1 Mini-SEED and Dataless SEED File Structure

The SEED Reference Manual [5] describes the format of SEED data files, including the specific variations known as "data only" SEED or Mini-SEED, which is used for PSE data, and dataless SEED, which contains metadata for the Mini-SEED files.
Each PSE product in SEED format is accompanied by a PDS4 label. An example label is given in Appendix B.

5.1.2 ASCII GeoCSV Table Data File Structure

Each Mini-SEED data file has a PDS-compliant ASCII table counterpart formatted as a comma-separated value (CSV) table. The table uses the GeoCSV convention for columns and header records as described in the GeoCSV documentation [[6]. In order to be PDS-compliant, the table must have only one set of header records, which must occur at the beginning of the file.
Each PSE product in ASCII CSV table format is accompanied by a PDS4 label. An example label is given in Appendix B.

5.1.3 ASCII StationXML Metadata File Structure

Each Dataless SEED file has a PDS-compliant ASCII text counterpart formatted as a StationXML file [[7]. Each StationXML file is accompanied by a PDS4 label. As both the StationXML file and PDS4 label are written in XML, and have the same base file name, they are distinguished by the file name extensions ".sxml" for StationXML and ".xml" for the PDS4 label.

5.2 Document Product Formats

Documents in this archive are provided as PDF/A (https://www.pdfa.org/publication/iso-19005-pdfa/) or as plain ASCII text if no special formatting is required. Figures that accompany documents may be embedded in the PDF/A files or provided as separate TIFF, GIF, JPEG, or PNG files.

5.3 PDS Labels

Each PSE product is accompanied by a PDS4 label. PDS4 labels are ASCII text files written in the eXtensible Markup Language (XML). Product labels are detached from the files they describe (with the exception of the Product_Bundle label). There is one label for every product. A PDS4 label file usually has the same name as the data product it describes, but always with the extension ".xml".

For the PSE archive, the structure and content of PDS labels will conform to the PDS master schema and schematron based upon the PDS Information Model [3]. By use of an XML editor the schema and schematron may be used to validate the structure and content of the product labels. In brief, the schema is the XML model that PDS4 labels must follow, and the schematron is a set of validation rules that are applied to PDS4 labels.
The PDS master schema and schematron documents are produced, managed, and supplied to the PSE team by the PDS. In addition to these documents, the PSE archive uses the Apollo Mission Dictionary, which contains XML schema and schematron files specific to the Apollo missions. The Apollo Mission Dictionary is produced and managed by the PDS Geosciences Node.
Examples of PDS labels for PSE data products are shown in Appendix B.

Appendix A Support Staff and Cognizant Persons

Table 8: Archive Support Staff

PSE		
Name	**Affiliation**	**Email**
Ceri Nunn	Jet Propulsion Laboratory (JPL)	ceri.nunn@jpl.nasa.gov
PDS Geosciences Node		
Name	**Affiliation**	**Email**
Paul Byrne, director	Washington University	paul.byrne@wustl.edu
Jennifer Ward	Washington University	jgward@wustl.edu

Appendix B Example Data Product Labels

This section provides examples of product labels for the various data types described in this document. The content of actual PSE data product labels may vary from these examples.

B.1 Dataless SEED Label

```
<?xml version='1.0' encoding='utf-8'?>
<?xml-model href="https://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1I00.sch"
    schematypens="http://purl.oclc.org/dsdl/schematron"?>
<?xml-model href="https://pds.nasa.gov/pds4/mission/apollo/v1/PDS4_APOLLO_1I00_1000.sch"
    schematypens="http://purl.oclc.org/dsdl/schematron"?>
<Product_Native
      xmlns="http://pds.nasa.gov/pds4/pds/v1"
      xmlns:apollo="http://pds.nasa.gov/pds4/mission/apollo/v1"
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xsi:schemaLocation="http://pds.nasa.gov/pds4/pds/v1
      https://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1I00.xsd
      http://pds.nasa.gov/pds4/mission/apollo/v1
      https://pds.nasa.gov/pds4/mission/apollo/v1/PDS4_APOLLO_1I00_1000.xsd">

  <Identification_Area>
    <logical_identifier>urn:nasa:pds:apollo_pse:data_seed:dataless.xa.0</logical_identifier>
    <version_id>1.0</version_id>
    <title>Apollo seismic Dataless SEED File</title>
    <information_model_version>1.18.0.0</information_model_version>
    <product_class>Product_Native</product_class>
    <Modification_History>
      <Modification_Detail>
        <modification_date>2022-08-13Z</modification_date>
        <version_id>1.0</version_id>
        <description>First release</description>
      </Modification_Detail>
    </Modification_History>
  </Identification_Area>
  <Context_Area>
    <Time_Coordinates>
      <start_date_time>1969-01-01T00:00:00Z</start_date_time>
      <stop_date_time>1977-09-30T18:50:00Z</stop_date_time>
    </Time_Coordinates>
    <Investigation_Area>
      <name>APOLLO 11</name>
      <type>Mission</type>
      <Internal_Reference>
```

```
      <lid_reference>urn:nasa:pds:context:investigation:mission.apollo_11</lid_reference>
      <reference_type>data_to_investigation</reference_type>
    </Internal_Reference>
  </Investigation_Area>
  <Investigation_Area>
    <name>APOLLO 12</name>
    <type>Mission</type>
    <Internal_Reference>
      <lid_reference>urn:nasa:pds:context:investigation:mission.apollo_12</lid_reference>
      <reference_type>data_to_investigation</reference_type>
    </Internal_Reference>
  </Investigation_Area>
  <Investigation_Area>
    <name>APOLLO 14</name>
    <type>Mission</type>
    <Internal_Reference>
      <lid_reference>urn:nasa:pds:context:investigation:mission.apollo_14</lid_reference>
      <reference_type>data_to_investigation</reference_type>
    </Internal_Reference>
  </Investigation_Area>
  <Investigation_Area>
    <name>APOLLO 15</name>
    <type>Mission</type>
    <Internal_Reference>
      <lid_reference>urn:nasa:pds:context:investigation:mission.apollo_15</lid_reference>
      <reference_type>data_to_investigation</reference_type>
    </Internal_Reference>
  </Investigation_Area>
  <Investigation_Area>
    <name>APOLLO 16</name>
    <type>Mission</type>
    <Internal_Reference>
      <lid_reference>urn:nasa:pds:context:investigation:mission.apollo_16</lid_reference>
      <reference_type>data_to_investigation</reference_type>
    </Internal_Reference>
  </Investigation_Area>
  <Observing_System>
    <Observing_System_Component>
      <name>APOLLO 11 EARLY APOLLO SCIENTIFIC EXPERIMENTS PACKAGE</name>
      <type>Host</type>
      <Internal_Reference>
        <lid_reference>urn:nasa:pds:context:instrument_host:spacecraft.a11e</lid_reference>
        <reference_type>is_instrument_host</reference_type>
      </Internal_Reference>
    </Observing_System_Component>
```

```
<Observing_System_Component>
  <name>APOLLO 12 LUNAR SURFACE EXPERIMENTS PACKAGE</name>
  <type>Host</type>
  <Internal_Reference>
    <lid_reference>urn:nasa:pds:context:instrument_host:spacecraft.a12a</lid_reference>
    <reference_type>is_instrument_host</reference_type>
  </Internal_Reference>
</Observing_System_Component>
<Observing_System_Component>
  <name>APOLLO 14 LUNAR SURFACE EXPERIMENTS PACKAGE</name>
  <type>Host</type>
  <Internal_Reference>
    <lid_reference>urn:nasa:pds:context:instrument_host:spacecraft.a14a</lid_reference>
    <reference_type>is_instrument_host</reference_type>
  </Internal_Reference>
</Observing_System_Component>
<Observing_System_Component>
  <name>APOLLO 15 LUNAR SURFACE EXPERIMENTS PACKAGE</name>
  <type>Host</type>
  <Internal_Reference>
    <lid_reference>urn:nasa:pds:context:instrument_host:spacecraft.a15a</lid_reference>
    <reference_type>is_instrument_host</reference_type>
  </Internal_Reference>
</Observing_System_Component>
<Observing_System_Component>
  <name>APOLLO 16 LUNAR SURFACE EXPERIMENTS PACKAGE</name>
  <type>Host</type>
  <Internal_Reference>
    <lid_reference>urn:nasa:pds:context:instrument_host:spacecraft.a16a</lid_reference>
    <reference_type>is_instrument_host</reference_type>
  </Internal_Reference>
</Observing_System_Component>
<Observing_System_Component>
  <name>Apollo 11 Passive Seismic Experiment (PSE)</name>
  <type>Instrument</type>
  <Internal_Reference>
    <lid_reference>urn:nasa:pds:context:instrument:pse.a11e</lid_reference>
    <reference_type>is_instrument</reference_type>
  </Internal_Reference>
</Observing_System_Component>
<Observing_System_Component>
  <name>Apollo 12 Passive Seismic Experiment (PSE)</name>
  <type>Instrument</type>
  <Internal_Reference>
    <lid_reference>urn:nasa:pds:context:instrument:pse.a12a</lid_reference>
```

```
        <reference_type>is_instrument</reference_type>
      </Internal_Reference>
    </Observing_System_Component>
    <Observing_System_Component>
      <name>Apollo 14 Passive Seismic Experiment (PSE)</name>
      <type>Instrument</type>
      <Internal_Reference>
        <lid_reference>urn:nasa:pds:context:instrument:pse.a14a</lid_reference>
        <reference_type>is_instrument</reference_type>
      </Internal_Reference>
    </Observing_System_Component>
    <Observing_System_Component>
      <name>Apollo 15 Passive Seismic Experiment (PSE)</name>
      <type>Instrument</type>
      <Internal_Reference>
        <lid_reference>urn:nasa:pds:context:instrument:pse.a15a</lid_reference>
        <reference_type>is_instrument</reference_type>
      </Internal_Reference>
    </Observing_System_Component>
    <Observing_System_Component>
      <name>Apollo 16 Passive Seismic Experiment (PSE)</name>
      <type>Instrument</type>
      <Internal_Reference>
        <lid_reference>urn:nasa:pds:context:instrument:pse.a16a</lid_reference>
        <reference_type>is_instrument</reference_type>
      </Internal_Reference>
    </Observing_System_Component>
  </Observing_System>
  <Target_Identification>
    <name>Moon</name>
    <type>Satellite</type>
    <Internal_Reference>
      <lid_reference>urn:nasa:pds:context:target:satellite.earth.moon</lid_reference>
      <reference_type>data_to_target</reference_type>
    </Internal_Reference>
  </Target_Identification>
  <Mission_Area>
    <apollo:Observation_Information>
      <apollo:product_type>Dataless-SEED</apollo:product_type>
    </apollo:Observation_Information>
    <apollo:Seismic_Parameters>
      <apollo:pse_data_type>metadata</apollo:pse_data_type>
      <apollo:ASCII_Equivalent>
        <apollo:ascii_equivalent_file_name>stationxml.xa.0.sxml</apollo:ascii_equivalent_file_name>
        <Internal_Reference>
```

```
            <lidvid_reference>urn:nasa:pds:apollo_pse:data_table:stationxml.xa.0::1.0</lidvid_reference>
            <reference_type>seed_to_ascii</reference_type>
          </Internal_Reference>
        </apollo:ASCII_Equivalent>
      </apollo:Seismic_Parameters>
    </Mission_Area>
  </Context_Area>
  <Reference_List>
    <Internal_Reference>
      <lid_reference>urn:nasa:pds:apollo_pse:document:apollo_pse_description</lid_reference>
      <reference_type>native_to_archival</reference_type>
    </Internal_Reference>
  </Reference_List>
  <File_Area_Native>
    <File>
      <file_name>dataless.xa.0.seed</file_name>
      <creation_date_time>2022-08-13T15:19:46.704098Z</creation_date_time>
    </File>
    <Encoded_Native>
      <name>Apollo PSE Dataless SEED</name>
      <offset unit="byte">0</offset>
      <encoding_standard_id>SEED 2.4</encoding_standard_id>
    </Encoded_Native>
  </File_Area_Native>
</Product_Native>
```

B.2 StationXML Label

```
<?xml version='1.0' encoding='utf-8'?>
<?xml-model href="https://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1I00.sch"
    schematypens="http://purl.oclc.org/dsdl/schematron"?>
<?xml-model href="https://pds.nasa.gov/pds4/mission/apollo/v1/PDS4_APOLLO_1I00_1000.sch"
    schematypens="http://purl.oclc.org/dsdl/schematron"?>
<Product_Ancillary
      xmlns="http://pds.nasa.gov/pds4/pds/v1"
      xmlns:apollo="http://pds.nasa.gov/pds4/mission/apollo/v1"
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xsi:schemaLocation="http://pds.nasa.gov/pds4/pds/v1
      https://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1I00.xsd
      http://pds.nasa.gov/pds4/mission/apollo/v1
      https://pds.nasa.gov/pds4/mission/apollo/v1/PDS4_APOLLO_1I00_1000.xsd">

  <Identification_Area>
    <logical_identifier>urn:nasa:pds:apollo_pse:data_table:stationxml.xa.0</logical_identifier>
    <version_id>1.0</version_id>
    <title>Apollo Passive Seismic Experiment metadata in StationXML format</title>
    <information_model_version>1.18.0.0</information_model_version>
    <product_class>Product_Ancillary</product_class>
    <Modification_History>
      <Modification_Detail>
        <modification_date>2022-08-13Z</modification_date>
        <version_id>1.0</version_id>
        <description>First release to Planetary Data System</description>
      </Modification_Detail>
    </Modification_History>
  </Identification_Area>
  <Context_Area>
    <Time_Coordinates>
      <start_date_time>1969-01-01T00:00:00Z</start_date_time>
      <stop_date_time>1977-09-30T18:50:00Z</stop_date_time>
    </Time_Coordinates>
    <Investigation_Area>
      <name>APOLLO 11</name>
      <type>Mission</type>
      <Internal_Reference>
        <lid_reference>urn:nasa:pds:context:investigation:mission.apollo_11</lid_reference>
        <reference_type>ancillary_to_investigation</reference_type>
      </Internal_Reference>
    </Investigation_Area>
    <Investigation_Area>
      <name>APOLLO 12</name>
```

```
    <type>Mission</type>
    <Internal_Reference>
      <lid_reference>urn:nasa:pds:context:investigation:mission.apollo_12</lid_reference>
      <reference_type>ancillary_to_investigation</reference_type>
    </Internal_Reference>
  </Investigation_Area>
  <Investigation_Area>
    <name>APOLLO 14</name>
    <type>Mission</type>
    <Internal_Reference>
      <lid_reference>urn:nasa:pds:context:investigation:mission.apollo_14</lid_reference>
      <reference_type>ancillary_to_investigation</reference_type>
    </Internal_Reference>
  </Investigation_Area>
  <Investigation_Area>
    <name>APOLLO 15</name>
    <type>Mission</type>
    <Internal_Reference>
      <lid_reference>urn:nasa:pds:context:investigation:mission.apollo_15</lid_reference>
      <reference_type>ancillary_to_investigation</reference_type>
    </Internal_Reference>
  </Investigation_Area>
  <Investigation_Area>
    <name>APOLLO 16</name>
    <type>Mission</type>
    <Internal_Reference>
      <lid_reference>urn:nasa:pds:context:investigation:mission.apollo_16</lid_reference>
      <reference_type>ancillary_to_investigation</reference_type>
    </Internal_Reference>
  </Investigation_Area>
  <Observing_System>
    <Observing_System_Component>
      <name>APOLLO 11 EARLY APOLLO SCIENTIFIC EXPERIMENTS PACKAGE</name>
      <type>Host</type>
      <Internal_Reference>
        <lid_reference>urn:nasa:pds:context:instrument_host:spacecraft.a11e</lid_reference>
        <reference_type>is_instrument_host</reference_type>
      </Internal_Reference>
    </Observing_System_Component>
    <Observing_System_Component>
      <name>APOLLO 12 LUNAR SURFACE EXPERIMENTS PACKAGE</name>
      <type>Host</type>
      <Internal_Reference>
        <lid_reference>urn:nasa:pds:context:instrument_host:spacecraft.a12a</lid_reference>
        <reference_type>is_instrument_host</reference_type>
```

```
  </Internal_Reference>
</Observing_System_Component>
<Observing_System_Component>
  <name>APOLLO 14 LUNAR SURFACE EXPERIMENTS PACKAGE</name>
  <type>Host</type>
  <Internal_Reference>
    <lid_reference>urn:nasa:pds:context:instrument_host:spacecraft.a14a</lid_reference>
    <reference_type>is_instrument_host</reference_type>
  </Internal_Reference>
</Observing_System_Component>
<Observing_System_Component>
  <name>APOLLO 15 LUNAR SURFACE EXPERIMENTS PACKAGE</name>
  <type>Host</type>
  <Internal_Reference>
    <lid_reference>urn:nasa:pds:context:instrument_host:spacecraft.a15a</lid_reference>
    <reference_type>is_instrument_host</reference_type>
  </Internal_Reference>
</Observing_System_Component>
<Observing_System_Component>
  <name>APOLLO 16 LUNAR SURFACE EXPERIMENTS PACKAGE</name>
  <type>Host</type>
  <Internal_Reference>
    <lid_reference>urn:nasa:pds:context:instrument_host:spacecraft.a16a</lid_reference>
    <reference_type>is_instrument_host</reference_type>
  </Internal_Reference>
</Observing_System_Component>
<Observing_System_Component>
  <name>Apollo 11 Passive Seismic Experiment (PSE)</name>
  <type>Instrument</type>
  <Internal_Reference>
    <lid_reference>urn:nasa:pds:context:instrument:pse.a11e</lid_reference>
    <reference_type>is_instrument</reference_type>
  </Internal_Reference>
</Observing_System_Component>
<Observing_System_Component>
  <name>Apollo 12 Passive Seismic Experiment (PSE)</name>
  <type>Instrument</type>
  <Internal_Reference>
    <lid_reference>urn:nasa:pds:context:instrument:pse.a12a</lid_reference>
    <reference_type>is_instrument</reference_type>
  </Internal_Reference>
</Observing_System_Component>
<Observing_System_Component>
  <name>Apollo 14 Passive Seismic Experiment (PSE)</name>
  <type>Instrument</type>
```

```
      <Internal_Reference>
        <lid_reference>urn:nasa:pds:context:instrument:pse.a14a</lid_reference>
        <reference_type>is_instrument</reference_type>
      </Internal_Reference>
    </Observing_System_Component>
    <Observing_System_Component>
      <name>Apollo 15 Passive Seismic Experiment (PSE)</name>
      <type>Instrument</type>
      <Internal_Reference>
        <lid_reference>urn:nasa:pds:context:instrument:pse.a15a</lid_reference>
        <reference_type>is_instrument</reference_type>
      </Internal_Reference>
    </Observing_System_Component>
    <Observing_System_Component>
      <name>Apollo 16 Passive Seismic Experiment (PSE)</name>
      <type>Instrument</type>
      <Internal_Reference>
        <lid_reference>urn:nasa:pds:context:instrument:pse.a16a</lid_reference>
        <reference_type>is_instrument</reference_type>
      </Internal_Reference>
    </Observing_System_Component>
  </Observing_System>
  <Target_Identification>
    <name>Moon</name>
    <type>Satellite</type>
    <Internal_Reference>
      <lid_reference>urn:nasa:pds:context:target:satellite.earth.moon</lid_reference>
      <reference_type>ancillary_to_target</reference_type>
    </Internal_Reference>
  </Target_Identification>
  <Mission_Area>
    <apollo:Observation_Information>
      <apollo:product_type>StationXML</apollo:product_type>
    </apollo:Observation_Information>
    <apollo:Seismic_Parameters>
      <apollo:pse_data_type>metadata</apollo:pse_data_type>
      <apollo:SEED_Equivalent>
        <apollo:seed_file_name>dataless.xa.0.seed</apollo:seed_file_name>
        <Internal_Reference>
          <lidvid_reference>urn:nasa:pds:apollo_pse:data_seed:dataless.xa.0::1.0</lidvid_reference>
          <reference_type>ascii_to_seed</reference_type>
        </Internal_Reference>
      </apollo:SEED_Equivalent>
    </apollo:Seismic_Parameters>
  </Mission_Area>
```

```
  </Context_Area>
  <Reference_List>
    <Internal_Reference>
      <lid_reference>urn:nasa:pds:apollo_pse:document:apollo_pse_description</lid_reference>
      <reference_type>ancillary_to_data</reference_type>
    </Internal_Reference>
  </Reference_List>
  <File_Area_Ancillary>
    <File>
      <file_name>stationxml.xa.0.sxml</file_name>
      <creation_date_time>2022-07-18T00:07:32.169121Z</creation_date_time>
    </File>
    <Stream_Text>
      <name>Apollo PSE StationXML</name>
      <offset unit="byte">0</offset>
      <parsing_standard_id>7-Bit ASCII Text</parsing_standard_id>
      <description>See StationXML documentation at http://www.fdsn.org/xml/station/.</description>
      <record_delimiter>Carriage-Return Line-Feed</record_delimiter>
    </Stream_Text>
  </File_Area_Ancillary>
</Product_Ancillary>
```

B.3 Mini-SEED Data Label

```
<?xml version='1.0' encoding='utf-8'?>
<?xml-model href="https://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1I00.sch"
    schematypens="http://purl.oclc.org/dsdl/schematron"?>
<?xml-model href="https://pds.nasa.gov/pds4/mission/apollo/v1/PDS4_APOLLO_1I00_1000.sch"
    schematypens="http://purl.oclc.org/dsdl/schematron"?>
<Product_Native
      xmlns="http://pds.nasa.gov/pds4/pds/v1"
      xmlns:apollo="http://pds.nasa.gov/pds4/mission/apollo/v1"
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xsi:schemaLocation="http://pds.nasa.gov/pds4/pds/v1
      https://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1I00.xsd
      http://pds.nasa.gov/pds4/mission/apollo/v1
      https://pds.nasa.gov/pds4/mission/apollo/v1/PDS4_APOLLO_1I00_1000.xsd">

  <Identification_Area>
    <logical_identifier>urn:nasa:pds:apollo_pse:data_seed:xa.s12.01.mhz.1976.061.0</logical_identifier>
    <version_id>1.0</version_id>
    <title>Apollo Passive Seismic Experiment data in MiniSEED format</title>
    <information_model_version>1.18.0.0</information_model_version>
    <product_class>Product_Native</product_class>
    <Modification_History>
      <Modification_Detail>
        <modification_date>2022-07-18Z</modification_date>
        <version_id>1.0</version_id>
        <description>First release to Planetary Data System</description>
      </Modification_Detail>
    </Modification_History>
  </Identification_Area>
  <Context_Area>
    <Time_Coordinates>
      <start_date_time>1976-03-01T00:01:44.813463Z</start_date_time>
      <stop_date_time>1976-03-02T00:00:03.832331Z</stop_date_time>
    </Time_Coordinates>
    <Investigation_Area>
      <name>APOLLO 12</name>
      <type>Mission</type>
      <Internal_Reference>
        <lid_reference>urn:nasa:pds:context:investigation:mission.apollo_12</lid_reference>
        <reference_type>data_to_investigation</reference_type>
      </Internal_Reference>
    </Investigation_Area>
    <Observing_System>
      <Observing_System_Component>
```

```
      <name>APOLLO 12 LUNAR SURFACE EXPERIMENTS PACKAGE</name>
      <type>Host</type>
      <Internal_Reference>
        <lid_reference>urn:nasa:pds:context:instrument_host:spacecraft.a12a</lid_reference>
        <reference_type>is_instrument_host</reference_type>
      </Internal_Reference>
    </Observing_System_Component>
    <Observing_System_Component>
      <name>Apollo 12 Passive Seismic Experiment (PSE)</name>
      <type>Instrument</type>
      <Internal_Reference>
        <lid_reference>urn:nasa:pds:context:instrument:pse.a12a</lid_reference>
        <reference_type>is_instrument</reference_type>
      </Internal_Reference>
    </Observing_System_Component>
  </Observing_System>
  <Target_Identification>
    <name>Moon</name>
    <type>Satellite</type>
    <Internal_Reference>
      <lid_reference>urn:nasa:pds:context:target:satellite.earth.moon</lid_reference>
      <reference_type>data_to_target</reference_type>
    </Internal_Reference>
  </Target_Identification>
  <Mission_Area>
    <apollo:Observation_Information>
      <apollo:product_type>Mini-SEED</apollo:product_type>
    </apollo:Observation_Information>
    <apollo:Seismic_Parameters>
      <apollo:pse_data_type>waveform</apollo:pse_data_type>
      <apollo:Metadata_Location>
        <apollo:metadata_file_name>dataless.xa.0.seed</apollo:metadata_file_name>
        <Internal_Reference>
          <lid_reference>urn:nasa:pds:apollo_pse:data_seed:dataless.xa.0</lid_reference>
          <reference_type>data_to_metadata</reference_type>
        </Internal_Reference>
      </apollo:Metadata_Location>
      <apollo:ASCII_Equivalent>
        <apollo:ascii_equivalent_file_name>xa.s12.01.mhz.1976.061.0.a.csv</apollo:ascii_equivalent_file_name>
        <Internal_Reference>
          <lidvid_reference>urn:nasa:pds:apollo_pse:data_table:xa.s12.01.mhz.1976.061.0.a::1.0</lidvid_reference>
          <reference_type>seed_to_ascii</reference_type>
        </Internal_Reference>
      </apollo:ASCII_Equivalent>
      <apollo:station>S12</apollo:station>
```

```
        <apollo:channel>MHZ</apollo:channel>
        <apollo:location>01</apollo:location>
        <apollo:sampling_rate unit="Hz">6.625</apollo:sampling_rate>
        <apollo:sample_count>571732</apollo:sample_count>
      </apollo:Seismic_Parameters>
    </Mission_Area>
  </Context_Area>
  <Reference_List>
    <Internal_Reference>
      <lid_reference>urn:nasa:pds:apollo_pse:document:apollo_pse_description</lid_reference>
      <reference_type>native_to_archival</reference_type>
    </Internal_Reference>
  </Reference_List>
  <File_Area_Native>
    <File>
      <file_name>xa.s12.01.mhz.1976.061.0.mseed</file_name>
      <creation_date_time>2022-07-18T14:09:13.957226Z</creation_date_time>
    </File>
    <Encoded_Native>
      <name>Apollo PSE MiniSEED Data</name>
      <offset unit="byte">0</offset>
      <encoding_standard_id>SEED 2.4</encoding_standard_id>
    </Encoded_Native>
  </File_Area_Native>
</Product_Native>
```

B.4 GeoCSV Label

```
<?xml version='1.0' encoding='utf-8'?>
<?xml-model href="https://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1I00.sch"
    schematypens="http://purl.oclc.org/dsdl/schematron"?>
<?xml-model href="https://pds.nasa.gov/pds4/mission/apollo/v1/PDS4_APOLLO_1I00_1000.sch"
    schematypens="http://purl.oclc.org/dsdl/schematron"?>
<Product_Observational
        xmlns="http://pds.nasa.gov/pds4/pds/v1"
        xmlns:apollo="http://pds.nasa.gov/pds4/mission/apollo/v1"
        xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
        xsi:schemaLocation="http://pds.nasa.gov/pds4/pds/v1
        https://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1I00.xsd
        http://pds.nasa.gov/pds4/mission/apollo/v1
        https://pds.nasa.gov/pds4/mission/apollo/v1/PDS4_APOLLO_1I00_1000.xsd">

  <Identification_Area>
    <logical_identifier>urn:nasa:pds:apollo_pse:data_table:xa.s12.01.mhz.1976.061.0.a</logical_identifier>
    <version_id>1.0</version_id>
    <title>Apollo Passive Seismic Experiment data in GeoCSV format</title>
    <information_model_version>1.18.0.0</information_model_version>
    <product_class>Product_Observational</product_class>
    <Modification_History>
      <Modification_Detail>
        <modification_date>2022-08-16Z</modification_date>
        <version_id>1.0</version_id>
        <description>First release to Planetary Data System</description>
      </Modification_Detail>
    </Modification_History>
  </Identification_Area>
  <Observation_Area>
    <Time_Coordinates>
      <start_date_time>1976-03-01T00:01:44.813463Z</start_date_time>
      <stop_date_time>1976-03-02T00:00:03.832330Z</stop_date_time>
    </Time_Coordinates>
    <Investigation_Area>
      <name>APOLLO 12</name>
      <type>Mission</type>
      <Internal_Reference>
        <lid_reference>urn:nasa:pds:context:investigation:mission.apollo_12</lid_reference>
        <reference_type>data_to_investigation</reference_type>
      </Internal_Reference>
    </Investigation_Area>
    <Observing_System>
      <Observing_System_Component>
```

```
      <name>APOLLO 12 LUNAR SURFACE EXPERIMENTS PACKAGE</name>
      <type>Host</type>
      <Internal_Reference>
        <lid_reference>urn:nasa:pds:context:instrument_host:spacecraft.a12a</lid_reference>
        <reference_type>is_instrument_host</reference_type>
      </Internal_Reference>
    </Observing_System_Component>
    <Observing_System_Component>
      <name>Apollo 12 Passive Seismic Experiment (PSE)</name>
      <type>Instrument</type>
      <Internal_Reference>
        <lid_reference>urn:nasa:pds:context:instrument:pse.a12a</lid_reference>
        <reference_type>is_instrument</reference_type>
      </Internal_Reference>
    </Observing_System_Component>
  </Observing_System>
  <Target_Identification>
    <name>Moon</name>
    <type>Satellite</type>
    <Internal_Reference>
      <lid_reference>urn:nasa:pds:context:target:satellite.earth.moon</lid_reference>
      <reference_type>data_to_target</reference_type>
    </Internal_Reference>
  </Target_Identification>
  <Mission_Area>
    <apollo:Observation_Information>
      <apollo:product_type>GeoCSV</apollo:product_type>
    </apollo:Observation_Information>
    <apollo:Seismic_Parameters>
      <apollo:pse_data_type>waveform</apollo:pse_data_type>
      <apollo:Metadata_Location>
        <apollo:metadata_file_name>stationxml.xa.0.sxml</apollo:metadata_file_name>
        <Internal_Reference>
          <lid_reference>urn:nasa:pds:apollo_pse:data_table:stationxml.xa.0</lid_reference>
          <reference_type>data_to_metadata</reference_type>
        </Internal_Reference>
      </apollo:Metadata_Location>
      <apollo:SEED_Equivalent>
        <apollo:seed_file_name>xa.s12.01.mhz.1976.061.0.mseed</apollo:seed_file_name>
        <Internal_Reference>
          <lidvid_reference>urn:nasa:pds:apollo_pse:data_seed:xa.s12.01.mhz.1976.061.0::1.0</lidvid_reference>
          <reference_type>ascii_to_seed</reference_type>
        </Internal_Reference>
      </apollo:SEED_Equivalent>
      <apollo:station>S12</apollo:station>
```

```
      <apollo:channel>MHZ</apollo:channel>
      <apollo:location>01</apollo:location>
      <apollo:sampling_rate unit="Hz">6.625</apollo:sampling_rate>
      <apollo:sample_count>571732</apollo:sample_count>
    </apollo:Seismic_Parameters>
  </Mission_Area>
</Observation_Area>
<Reference_List>
  <Internal_Reference>
    <lid_reference>urn:nasa:pds:apollo_pse:document:apollo_pse_description</lid_reference>
    <reference_type>data_to_document</reference_type>
  </Internal_Reference>
</Reference_List>
<File_Area_Observational>
  <File>
    <file_name>xa.s12.01.mhz.1976.061.0.a.csv</file_name>
    <creation_date_time>2022-08-16T21:27:41.080747Z</creation_date_time>
  </File>
  <Header>
    <name>Table 1 Comments</name>
    <offset unit="byte">0</offset>
    <object_length unit="byte">213</object_length>
    <parsing_standard_id>7-Bit ASCII Text</parsing_standard_id>
    <description>See GeoCSV documentation at http://geows.ds.iris.edu/documents/GeoCSV.pdf.</description>
  </Header>
  <Header>
    <name>Table 1 Column Headings</name>
    <offset unit="byte">213</offset>
    <object_length unit="byte">14</object_length>
    <parsing_standard_id>PDS DSV 1</parsing_standard_id>
    <description>Comma-separated names of columns in the data table</description>
  </Header>
  <Table_Delimited>
    <name>Table 1 in Apollo GeoCSV File xa.s12.01.mhz.1976.061.0.a.csv</name>
    <offset unit="byte">227</offset>
    <parsing_standard_id>PDS DSV 1</parsing_standard_id>
    <records>571732</records>
    <record_delimiter>Carriage-Return Line-Feed</record_delimiter>
    <field_delimiter>Comma</field_delimiter>
    <Record_Delimited>
      <fields>2</fields>
      <groups>0</groups>
      <Field_Delimited>
        <name>Time</name>
        <field_number>1</field_number>
```

```
          <data_type>ASCII_Date_Time_YMD_UTC</data_type>
        </Field_Delimited>
        <Field_Delimited>
          <name>Sample</name>
          <field_number>2</field_number>
          <data_type>ASCII_Integer</data_type>
          <description>
            Raw counts from miniSEED file.
          </description>
          <Special_Constants>
            <missing_constant>-1</missing_constant>
          </Special_Constants>
        </Field_Delimited>
      </Record_Delimited>
    </Table_Delimited>
  </File_Area_Observational>
</Product_Observational>
```