Psyche Project

Science Data Management Plan

Revision A

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Signature Page

Prepared by:

_____

Daniel Wenkert Date
Psyche Mission Archive Scientist

Approved:

_____

Linda Elkins-Tanton Date
Psyche Principal Investigator

_____

Sarah Noble Date
Psyche Program Scientist

_____

William Knopf Date
Psyche Program Executive

_____

Bradley Zavodsky Date
Planetary Missions Program Office

_____

Carol Polanskey Date
Psyche Project Scientist

_____

Henry Stone Date
Psyche Project Manager

_____

Robert Mase Date
Psyche Deputy Project Manager

_____

James Bauer Date
PDS Small Bodies Node PI

_____

Eric Palmer Date
PDS Small Bodies Node Asteroid/Dust Sub-node PI

_____

Tim McClanahan Date
PDS Project Manager

Concurrence Page

Concurred by:

James Bell, Date
Imager Investigation Lead Co-I

Michael Walworth Date
Imager Data Archiving Lead

Ernest Cisneros Date
Science Data Center Manager

Benjamin Weiss Date
Psyche Deputy Principal Investigator and Magnetometry Investigation Lead Co-I

Jodie Ream, Date
Magnetometer Data Archiving Lead

David Lawrence, Date
GRNS Investigation Lead Co-I

Patrick Peplowski, Date
GRNS Data Archiving Lead

Maria Zuber, Date
Gravity Science Investigation Lead Co-I

Ryan Park, Date
Gravity Data Archiving Lead

Ralf Jaumann, Date
Topography Working Group Lead

David Williams, Cartography Lead	Date
Marla Thornton, Psyche Ground Data System Lead	Date

EPDM Electronic Signatures

Snapshot of signatures from EPDM will be added upon release

CHANGE LOG

DATE	Sections Changed	DESCRIPTION	REVISION
10/03/2016	All	New document	Draft
10/20/2016	All	Removed references to CSR and the Cartography Plan.	Draft
11/20/2017	All	Formatting clean-up, no content change	Draft
4/20/2017	All	Added page numbers, no content change	Draft
10/03/2018	Various Section 5.3.	Made changes based on Ernest Cisneros's comments in April 2018 to the proposal version of this plan. Added schedules for and descriptions of PDS reviews (pipeline and non-pipeline).	Draft
10/6/2018	Signature page Concurrence page Section 5.3	Made changes based on comments from Carol Neese's review of plan on 10/16/2017 and in her email of 10/4/2018.	Draft
11/20/2018	All (especially data volume tables)	Changes based on comments/edits from Ernest Cisneros and Carol Neese.	Draft
12/13/2018	All (especially data volume tables)	Changes based on comments/edits from Jodie Ream, Ryan Park, Patrick Peplowski, and David Williams.	Draft
12/27/2020	Data Product table (Table 4-1)	Changes based on inputs from all investigation teams	Preliminary
2/11/2020	Figures 2-2 to 2-8 Figures 4-1 to 4-5 and Tables 4-1 and 4-2	Changes based on input from teams and decision to make process to generate higher level products from imagery easier to understand Changes based on input from GRNS team and decision to create a separate SPICE kernels bundle	
3/05/2020	Section 1	Updated documents	
3/12/2020 – 3/18/2020	Section 2 Sections 2.0-5.2 Section 4.1.1 Section 4.1.4 Section 4.1.7	Small changes to Table 2-4 (still need updates to all numbers). Many small changes and many comments added. Updated for addition of new Magnetometer data product. Updated for split between GRS and NS data products. Now states that nearly all engineering data will be archived (TBD)	

3/19/2020	Sections 5.3-6	More small changes and several comments added.	
3/17/2020 - 3/22/2020	All	Updates based on input from DAWG, including especially Carol Polanskey, involving data products generated based upon Imager data. Includes inputs from instrument teams on data volumes for each segment of science phase and specific details of their investigations.	
3/24/2020	Tables 2-2, 2-4, 4-1, and 4-2 Front material	All data volume numbers checked with teams and updated. Includes changes to how instruments may be operated and the change from UCLA magnetometer to DTU magnetometer. Removed Table of Figures and Table of Tables.	Initial
9/30/2020	All	Updates for Psyche Mission Systems CDR. Especially, modifications based on inputs from Marla Thornton, the GDS lead.	A
3/08/2021	Section 4.1.4 (all sections were checked)	Updated any non-standard data level descriptions to have PDS4 terms first and NASA data levels second	A
4/11/2022	All sections, especially 4.1 and 6	Updated bundle figures (Figures 4.1 through 4-7) and bundle table (Table 4-1). Updated delivery schedule figure (Figure 6-1) and added schedule table (Table 6-1).	A
5/01/2023	Sections 5 and 6 and Appendix	Extensive modifications to schedule tables and to text describing deliveries, especially in cruise and for final high-level Derived products in late portion of orbital mission.	A
6/12/2023	Sections 2, 4, 5, and Appendix	Updated all data volume numbers, to account for changes in orbit plan at (16) Psyche. Updated references to SPICE and NAIF and ancillary data, including in figures, based on inputs from Boris Semenov (NAIF).	A
6/22/2023	All	Removed all references to subset of Imager team (from DLR etc.) and	A

		their generation of a topography product based on SPG.	
7/12/2023	Section 4.1.7, Table 4-2	Removed most references to engineering data that are not incorporated in the science data products. Left in a statement about a possible eventual best-efforts-basis attempt to include more comprehensive engineering data.	A
7/12/2023	Section titled "Items To Be Modified and/or Changed in Future Drafts" (see below)	Removed references to everything except to possible updates of actual mission timeline and PDS delivery dates.	A
8/07/2023	Section 1.1	Incorporated final review comments from investigation leads. Corrected mapping of data levels from PDS4 to NASA.	A

Items To Be Modified and/or Changed in Future Drafts

The following items will be updated in (or added to) this plan. This design has been reviewed by the Archiving Leads and all members of the Data Archiving Working Group (DAWG).

- Mission timeline: Mission dates are the current best estimate based on the nominal launch date in October 2023, and the trajectory plan approved by the project and program in January 2023. Delivery dates relative to mission events will be preserved, but actual dates may vary. Schedules will be negotiated with the PDS based on the executed mission timeline.
- Erratum: Some Figures in this document use an incorrect mapping of PDS4 levels to NASA levels. The figures will be corrected in the next revision. Reference Table 2-2 and Table 2-3 for the correct mapping.
- References to instrument papers published by Space Science Reviews will be added after their publication.

Table of Contents

1 Introduction to Science Data Management Plan

1.1 Purpose and scope

This Psyche Science Data Management Plan (SDMP) describes the mission-level plan for generating, validating, and transferring Psyche archival data and documentation to NASA's Planetary Data System (PDS) archives. In addition to outlining the data archive plan, this document also contains the Psyche data release and use policy that defines how the Psyche team manages data distribution and release with Psyche's science team, the scientific community, and the general public. Development schedules associated with the Psyche archive process are included in Section 6. These have been developed with input from the PDS Small Bodies Node (SBN).

This Psyche Science Data Management Plan encompasses all scientific data acquired by the instruments and the gravity experiment on the Psyche spacecraft and higher-level data products generated by the Psyche project. It covers raw, partially processed, calibrated, and derived data (Levels 0–3), and the accompanying information to be generated by the Psyche Project.

Specifics addressed in this plan are:

- Generation of high-level project, spacecraft, and instrument documentation; instrument calibration reports; and documentation of algorithms and/or software used to generate raw and higher-level data products.
- Acquisition of raw science data (CCSDS File Delivery Protocol (CFDP) product files) and engineering data (housekeeping telemetry).
- Distribution of these data to the Psyche Science Data Center (SDC) at Arizona State University (ASU) and from there to the Science Team.
- Generation and validation of instrument data products (raw, partially processed, and calibrated), with associated documentation.
- Generation and validation of higher-level data products (derived), with associated documentation.
- Generation and validation of SPICE archives.
- Generation and validation of PDS-compliant archives containing Psyche science and engineering data, instrument data products, higher level data products, algorithms, documentation, and ancillary information.
- Policies and procedures for generating and validating Psyche archival data products and transferring them to the PDS.
- Delivery of validated Psyche archives to the PDS.
- Distribution of archival data products through the PDS.
- Distribution of public data products, specifically the raw images, by the Psyche Project.

1.2 Contents and definitions

This plan begins with overviews of the Psyche Project, the SDC at ASU, and the PDS. This is followed by a summary of roles and responsibilities for generating, validating, transferring, and distributing Psyche archival products and public data. Next is a more detailed discussion of the data products to be generated by the Psyche Project, and policies for data sharing and distribution. The document continues with a description of the Psyche archiving process, including data flow. Finally, the *end-to-end data management schedule* is described.

Throughout this plan, 1 Byte (B) equals 8 bits (b), Mb means 10^6 bits, MB means 10^6 Bytes, Gb means 10^9 bits, GB means 10^9 Bytes, etc. Throughout this plan, a science product is referred to as a "data product." The Psyche project has no non-data science products (no rock samples, for example). The

Psyche project has no ground-based observations of asteroid (16) Psyche. This plan is referred to as the "Science Data Management Plan."

1.3 Controlling and reference documents

This plan is responsive to the following Discovery Program and Psyche documents:

- Discovery 2014 Announcement of Opportunity NNH14ZDA014O
- Psyche Concept Study Report
- Psyche Project Plan, JPL D-100146.

This plan is also consistent with the following Planetary Data System documents:

- Planetary Data System Standards Reference, JPL D-7669, Part 2, Version 1.17.0.
- PDS4 Data Provider's Handbook, Guide to Archiving Planetary Data Using the PDS4 Standard, Version 1.17.0.
- PDS4 Data Dictionary, Version 1.17.0.
- PDS4 Concepts, Version 1.17.0.
- Data Processing Levels (for PDS4), (Policy on Data Processing Levels), Version 7-1-1, 2013-03-11.

This plan requires the generation of the following project documents:

- Memorandum of understanding (MOU) between the Psyche project and the Planetary Data System (PDS) to briefly outline the scope and responsibilities for the archive (approved and signed on January 29, 2018).
- Interface Control Document (ICD) specifying relationships between the Psyche project, instrument science teams, and the PDS Small Bodies Node (SBN) (finalized in Phase C).
- Psyche Science Data Management Plan [this document; preliminary draft at proposal, draft at Preliminary Design Review (PDR), final at Mission System Critical Design Review (MS CDR)], update at Operations Readiness Review (ORR).
- Data Product Software Interface Specification (SIS) for all standard products (draft versions at CDR and final versions at Pipeline Certification for Raw, Partially Processed, and Calibrated data products and at preliminary delivery for Derived data products [see Table 6-1)].
- Archive Software Interface Specifications (SIS) for all standard products (draft at CDR, final at ORR).

Finally, this plan is intended to be consistent with:

- Psyche Project Level 1 requirements
- Contracts negotiated between the Psyche Project, Principal Investigator (PI), and Co-Investigators (Co-Is), in which archival and public data, product generation algorithms, and documentation are explicitly defined as deliverables.
- Psyche mission-level plans for archiving software used in processing Psyche data, in compliance with SPD-41.
- Psyche Project Communications Plan, JPL D-100144.

2 Overview

2.1 Mission overview

The Psyche spacecraft will be launched in October 2023 and arrive at the asteroid (16) Psyche in August 2029. The Science Phase is divided into five segments, designated A, B1, D, C, and B2, in temporal order. Orbits A through D are named such because they have successively smaller semi-major axes. Each science phase segment has specific purposes and is followed by a period of thrusting designed to move to the next orbit semi-major axis (until the final Orbit B2 and end of mission).

The Psyche mission has the five following science objectives.

1. Determine whether Psyche is a core, or if it is unmelted material
2. Determine the relative ages of regions of Psyche's surface.
3. Determine whether small metal bodies incorporate the same light elements as are expected in the Earth's high-pressure core.
4. Determine whether Psyche was formed under conditions more oxidizing or more reducing than Earth's core.
5. Characterize Psyche's morphology.

2.2 Psyche instrumentation and standard data products

The science payload comprises three instruments and the communications system (used for gravity science):

- Magnetometer (magnetometer),
- Multispectral Imagers (imagers),
- Gamma-Ray and Neutron Spectrometer (GRNS), and
- Gravity Science (gravity), which uses the X-band communications subsystem and DSN as an instrument.

These four investigations are described in more detail elsewhere.

The investigations, along with scientist roles, are listed below in Table 2-1.

The specific types of science-related archival data products to be produced during the Psyche project are described in this plan, including standard data products, ancillary products, and documentation that accompany these data as they are delivered to the PDS. For reference, Table 2-2 defines processing levels, using the common assignments developed by the NASA community. Use and distribution of these different types of archival data products are described below.

The Psyche Science Team generates the standard data products listed in Tables 2-3, 2-4 and 4-1 (as described below in §2.3 and §4.1). Note that the estimated data volume from each science phase segment (orbit) is listed for each lower-level standard data product. These numbers do not include any data from the operations margin at the end of Orbit B2 operations.

Table 2–1. Each science element (three instrument payloads, radio science, and ancillary data) has its own archiving lead.

Investigation/Instrument	Investigation Lead Co-I	Data Archiving Lead
Magnetometer - Two fluxgate magnetometers (1 inboard + 1 outboard)	Benjamin Weiss (MIT)	Jodie Ream (MIT)
Imager - Two multispectral imagers (1 primary + 1 redundant)	James Bell (ASU)	Michael Walworth (ASU)
GRNS - Gamma-ray and neutron spectrometers	David Lawrence (APL)	Patrick Peplowski (APL)
Gravity - X-band radio science	Maria Zuber (MIT)	Ryan Park (JPL)
Ancillary data - SPICE kernels (e.g. spacecraft location and pointing)	N/A	Boris Semenov (JPL/NAIF)
Ancillary data - non-SPICE data	N/A	Ernest Cisneros (ASU)

Table 2–2. Definitions of processing levels for science data.

NASA	CODMAC	PDS3	PDS4	Description
Packet	1 (Raw)	ODR	Telemetry	An encoded byte stream used to transfer data from one or more instruments to temporary storage where the raw instrument data will be extracted. PDS does not archive telemetry data.
Level 0	2 (Edited)	EDR	Raw	Original data from an instrument. If compression, reformatting, packetization, or other translation has been applied to facilitate data transmission or storage, those processes will be reversed so that the archived data are in a PDS-approved archive format.
Level 1A			Partially Processed	Data that have been processed beyond the raw stage but which have not yet reached calibrated status.
Level 1B	3 (Calibrated)	RDR	Calibrated	Data converted to physical units, which makes values independent of the instrument.
Level 2	4 (Resampled)	DDR	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 used to interpret observational data, such as calibration tables or tables of viewing geometry, should also be classified as derived data if not easily matched to one of the other categories.
Level 3	5 (Derived)			
Level 4	6 (Ancillary)			

Table 2–3. Psyche's 14 lower-level data products cover all basic measurements made by the spacecraft.

Investigation/Instrument	PDS4 Data Level (NASA Level)	Data Product Description
Magnetometer	Raw (L0)	Time-stamped, raw orthogonal field components
	Partially-processed (L1A)	Time series of partially calibrated magnetic field vectors
	Calibrated (L1B)	Time series of calibrated spacecraft-field-corrected magnetic field vectors
	Derived (L2)	Time Series of rotated magnetic field vectors in J2000, body, and body-Sun frames (nT)
Imager	Raw (L0)	Binary images
	Calibrated (L1B)	Radiance images
Gamma-ray Spectrometer (GRS)	Raw (L0)	Time series of GRS counts
	Calibrated (L1B)	Time series of gamma-ray spectra
Neutron Spectrometer (NS)	Raw (L0)	Time series of raw NS counts
	Calibrated (L1B)	Time series of neutron spectra
Gravity Science	Raw (L0)	Radio Metric Tracking Data
	Raw (L0)	Media Calibration File
	Raw (L0)	Spacecraft Mass History File
	Raw (L0)	Spacecraft Small-Forces File

Table 2–4. Psyche's 4 science investigations generate 14 lower-level data products, at volumes (GB) that depend on mission phase.

	Data Product Collection	Cruise	Approach	Orbit A	A → B1	Orbit B1	B1 → D	Orbit D	D → C	Orbit C	C → B2	Orbit B2	Total
MAG	Raw (L0)	1323.96	136.00	76.16	23.12	125.12	133.28	136.00	122.4.0	136.00	31.28	227.12	2470.44
	Partially-processed (L1A)	1323.96	68.00	38.08	11.56	62.56	66.64	68.00	61.20	68.00	15.64	113.56	1897.20
	Calibrated (L1B)	525.69	27.00	15.12	4.59	24.84	26.46	27.00	24.30	27.00	6.21	45.09	753.30
	Derived (L2)	31.152	1.60	0.896	0.272	1.472	1.568	1.60	1.44	1.60	0.368	2.672	44.64
Imager	Raw (L0)	20.2	9.4	33.1	4.1	297.5	4.1	8.0	4.1	490.9	4.1	323.4	1198.8
	Calibrated (L1B)	40.5	18.7	66.3	8.1	595.0	8.1	15.9	8.1	981.9	8.1	646.8	2397.5
GRS	Raw (L0)	7.0	0.3	0.4	0.1	0.2	2.3	9.3	1.6	0.1	0.3	0.2	21.4 GB
	Calibrated (L1B)	7.0	0.3	0.4	0.1	0.2	2.3	9.3	1.6	0.1	0.3	0.2	21.4 GB
NS	Raw (L0)	3.5	0.2	0.1	<0.05	0.15	0.5	2.2	0.4	0.05	0.2	0.15	7.4 GB
	Calibrated (L1B)	3.5	0.2	0.1	<0.05	0.15	0.5	2.2	0.4	0.05	0.2	0.15	7.4 GB
Gravity	Raw (L0) Radio Metric	0	7.9	4.4	0	7.2	0	7.9	0	7.9	0	7.9	43
	Raw (L0) Media Cal	0	1.25 MB	0.7 MB	0	1.15 MB	0	1.25 MB	0	1.25 MB	0	1.25 MB	6.7 MB
	Raw (L0) Mass History												<1 MB
	Raw (L0) Small-Forces	0	12 MB	7 MB	0	12 MB	0	12 MB	0	12 MB	0	12 MB	67 MB

2.3 Science data processing flow

The Psyche Ground Data System (GDS) at JPL processes raw Psyche science data and provides data product files containing instrument data packets (called flight software data products; see Section 4.1). These are acquired by the SDC at ASU and instrument teams, from a File Exchange Interface (FEI) server in the GDS ("Psyche Science Server" in figures below). The Psyche GDS also processes engineering/housekeeping data from Psyche instruments and makes these available for pickup. Each science product generated (standard, intermediate, or experimental) is rapidly (e.g., immediately, daily, or weekly) transferred and stored at the SDC for use by any member of the Psyche Science Team. All standard data products are delivered to the SDC in PDS4-compatible form. These products are delivered by the SDC to the PDS for review and archiving at three-month intervals, starting six months after the mission starts the approach phase (which begins 100 days before the spacecraft arrives in Orbit A at (16) Psyche). The overall flow of science data is shown in Figure 2-1 below.

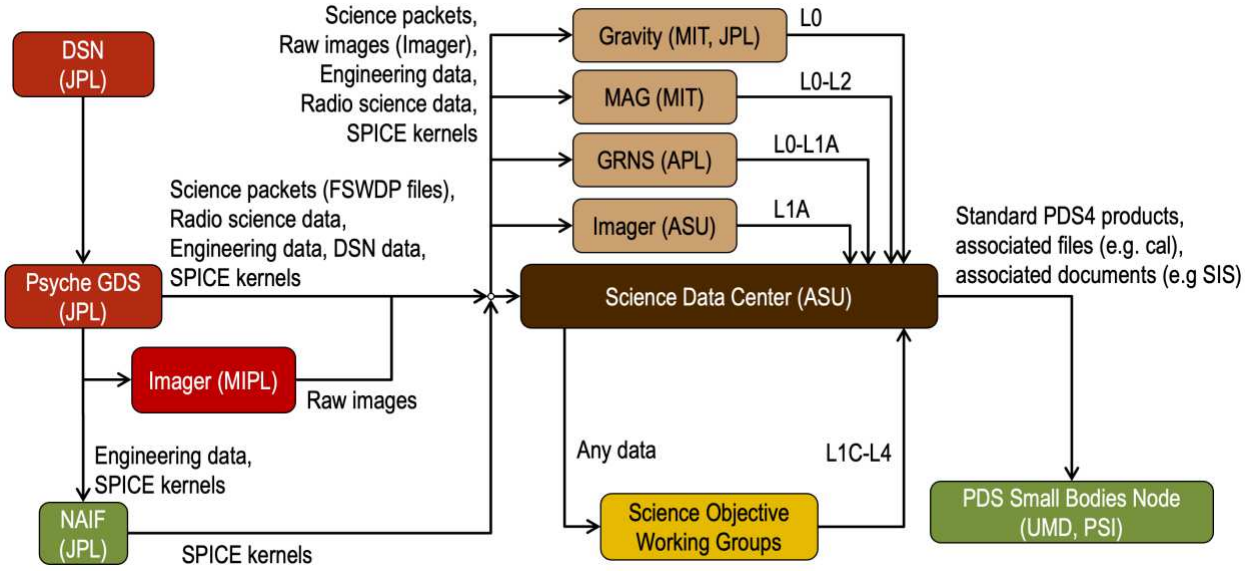

Figure 2–1. All input data flows into the Science Data Center and the instrument team data processing centers. Data are processed and returned to the SDC. The small circle to the left of the Science Data Center box represents the File Exchange Interface (FEI) server from which each of the investigation teams can acquire all of their input data.

Each instrument team is responsible for generating Raw, Partially Processed, and Calibrated (NASA Levels 0, 1A, and 1B, respectively) data products and delivering them to the SDC in PDS4-compatible form. The Science Objective Working Groups oversee generation of and/or develop higher-level Derived (Levels 2 through 4) data products. Actual product generation for many of these is done by the investigation teams (instrument teams and gravity science team). Known products are listed in this document (in Table 4-1, Section 4.1, and Figures 4-1 through 4-7). The Psyche mission Science Objectives are listed above in Section 2.1.

On behalf of the Objective 1 working group, the Magnetometer team generates and delivers single-instrument Derived (Levels 2 and 3) data products. The GRNS team does the same on behalf of the Objective 1, 3, and 4 working groups. The Gravity team delivers Raw data products to the SDC in PDS4-compatible form, as well as generating Derived (Level 3) data products on behalf of the Objective 1 working group. Based on the Calibrated (Level 1B) images, the Imager team generates Derived (L2) global image mosaics and the Gravity team generates a Derived (L3) tessellated plates shape model (a SPICE DSK file), on behalf of the Topography (Objective 5) working group. The Imager Team also

generates Derived (L3) spectral parameter maps on behalf of the Objective 3 and 4 working groups. The Cartography Lead is responsible for coordinating the production of the Derived (L4) global geologic maps. See Figures 2-2 through 2-8 below. As described above, each investigation's data contributes to Psyche science objectives. More Derived products will be defined in the future by the Science Objective Working Groups. Many of these are expected to include inputs from multiple investigations.

The standard data products described below meet the Psyche Level 1 science requirements. In addition to these standard products, other products (to be defined at a later date) will be generated by new Participating Scientists and various science team working groups (e.g. the Light Elements working group).

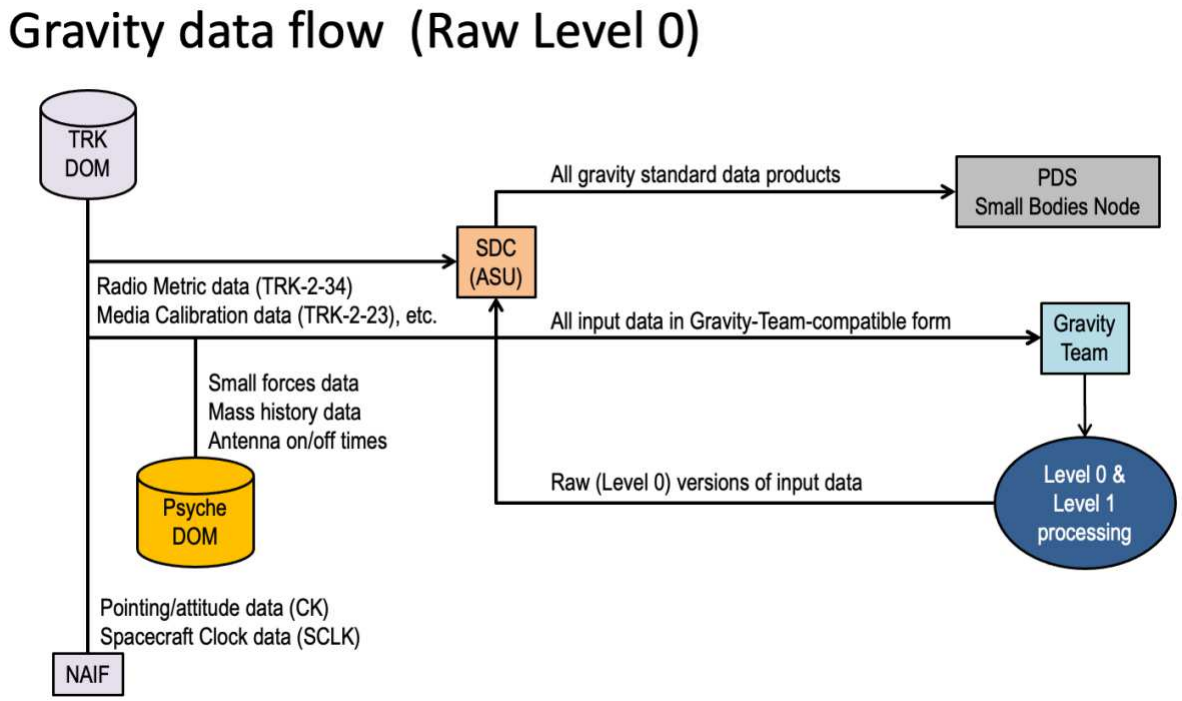

Figure 2–2. Primary Gravity Team science data processing inputs are DSN standard products and spacecraft engineering data.

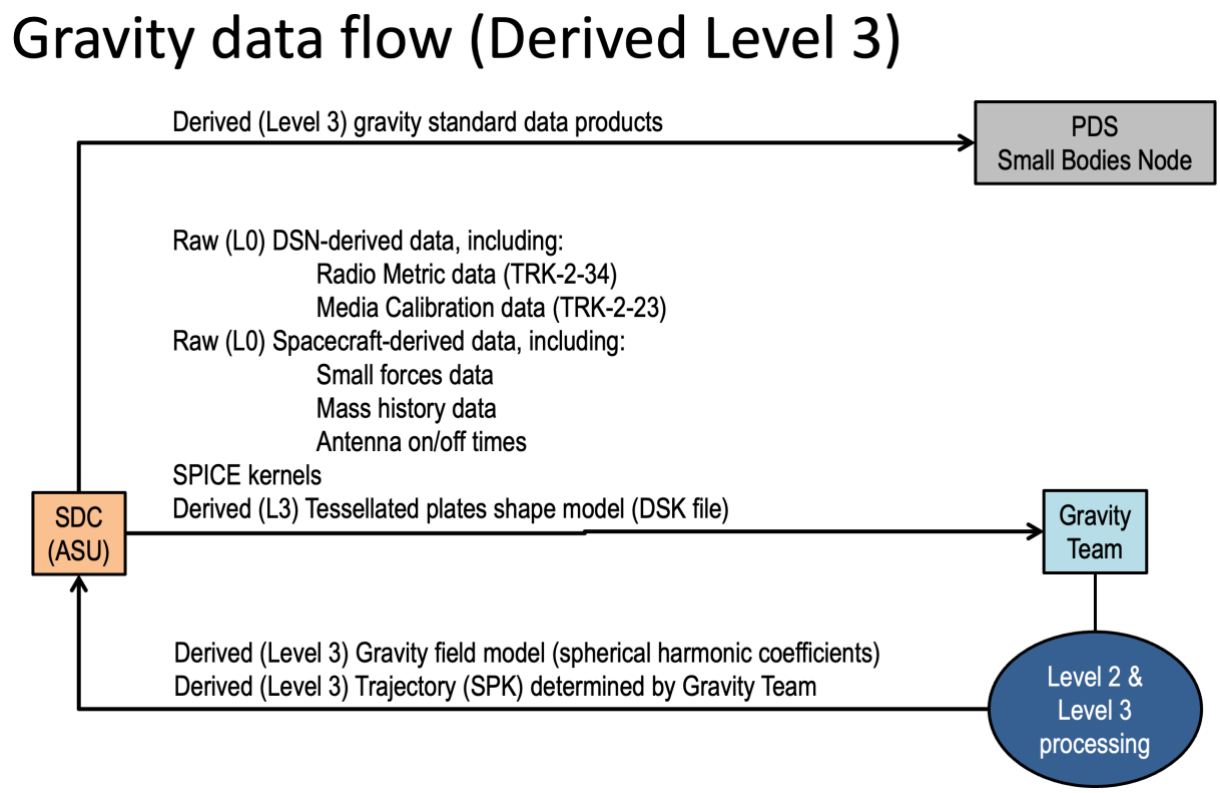

Figure 2–3. The global gravity field model helps satisfy Science Objective 1. It requires shape information input derived from Imager data (see Figure 2-7 below).

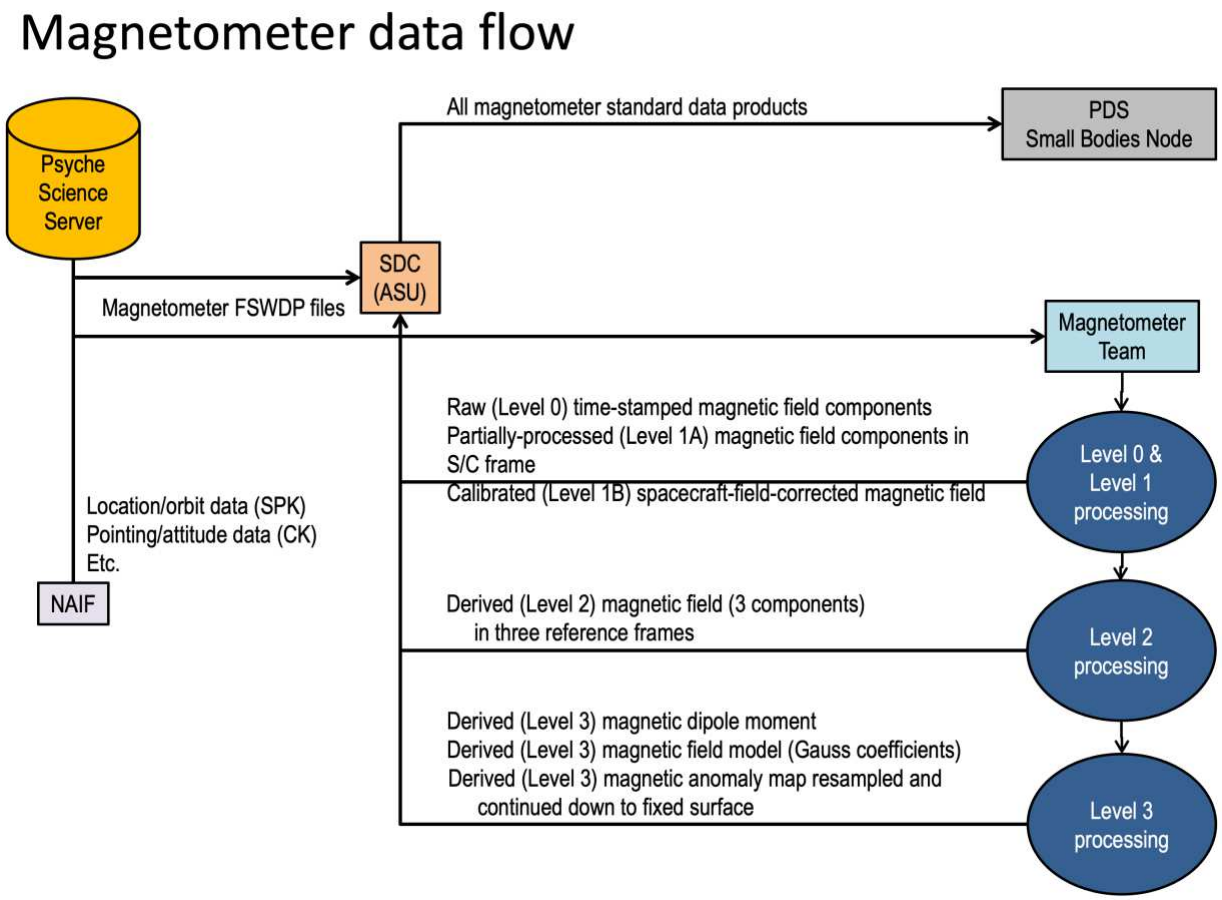

Figure 2–4. The global magnetic field model and map help satisfy Science Objective 1.

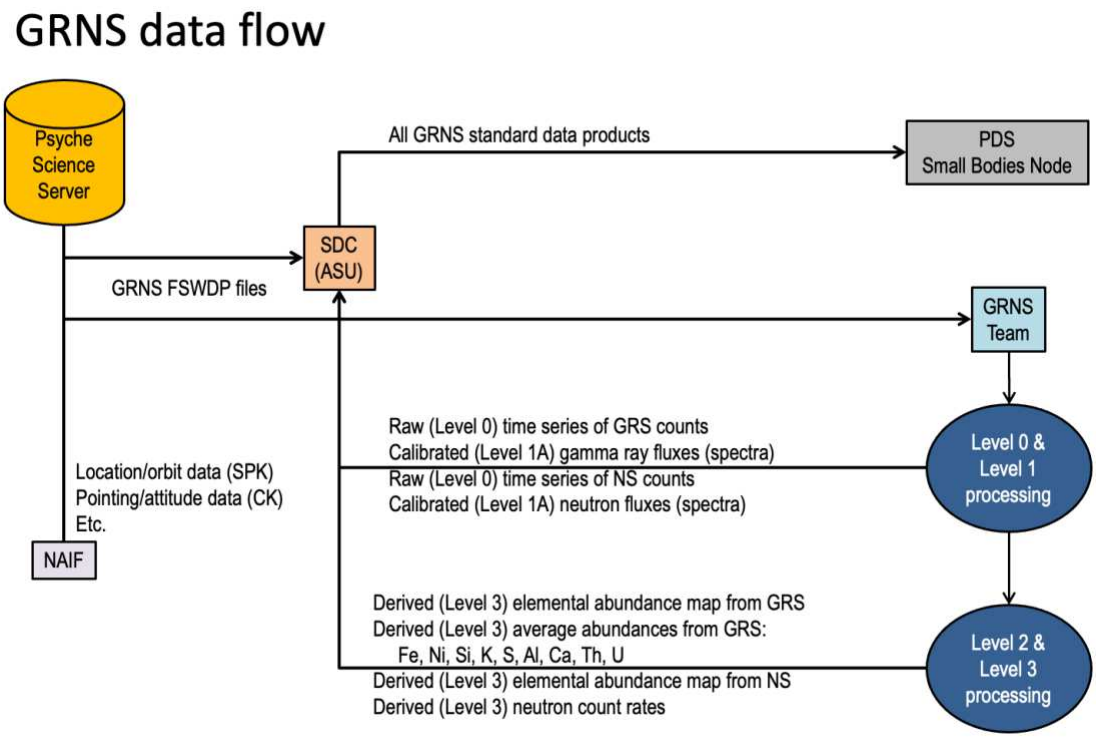

Figure 2–5. The GRNS global average elemental composition and composition map help satisfy Science Objectives 1, 3, and 4.

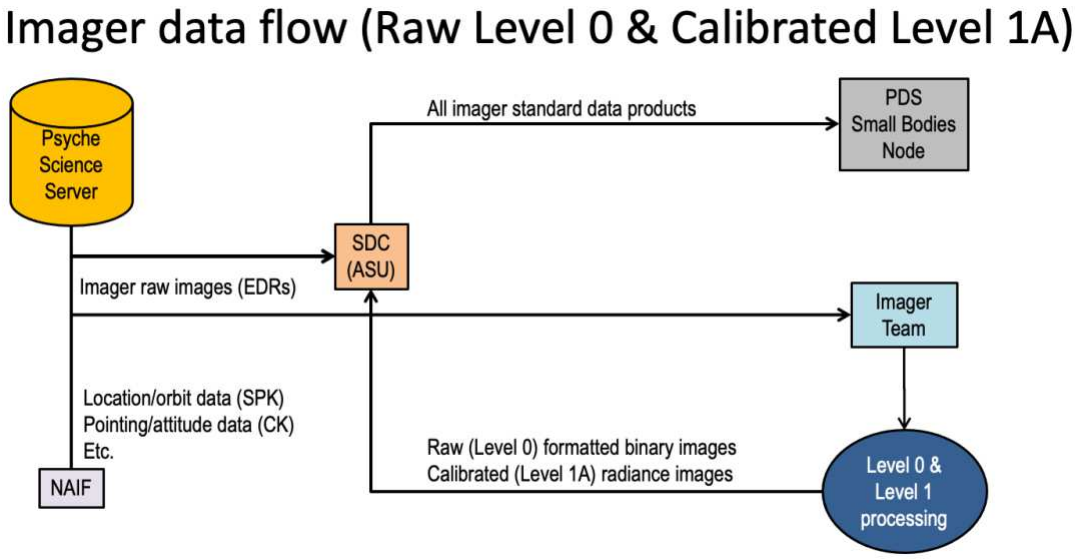

Figure 2–6. Raw (Level 0) images are retrieved from JPL and Calibrated (Level 1B) image products are generated. These products enable the generation of global image mosaics and topographic, geologic, and spectral parameter maps (see below).

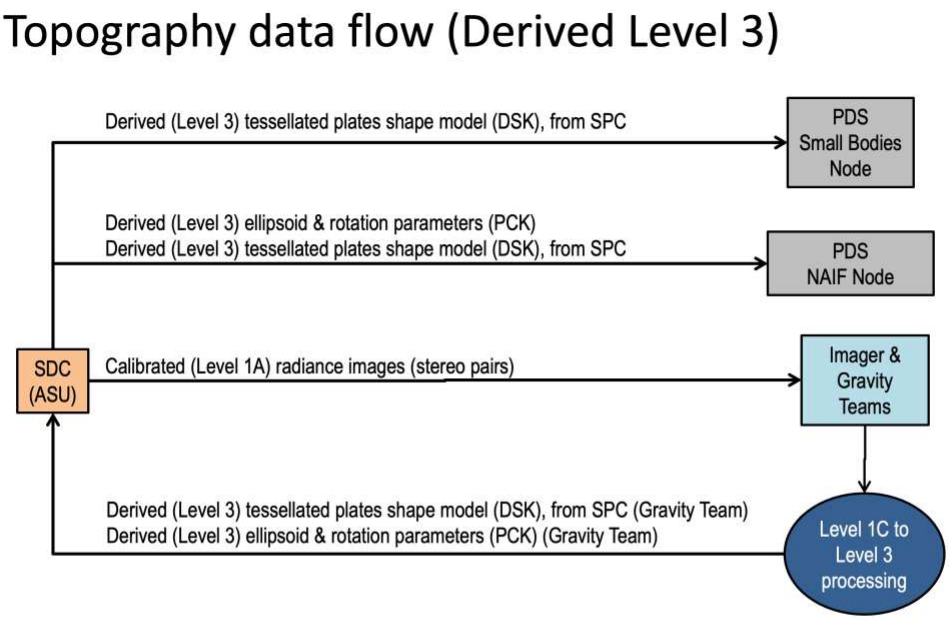

Figure 2–7. The Imager Team and Topography working group and the Gravity Team generate shape models that help satisfy Science Objective 5, and enable generation of image mosaics and geologic and spectral parameter maps (see below).

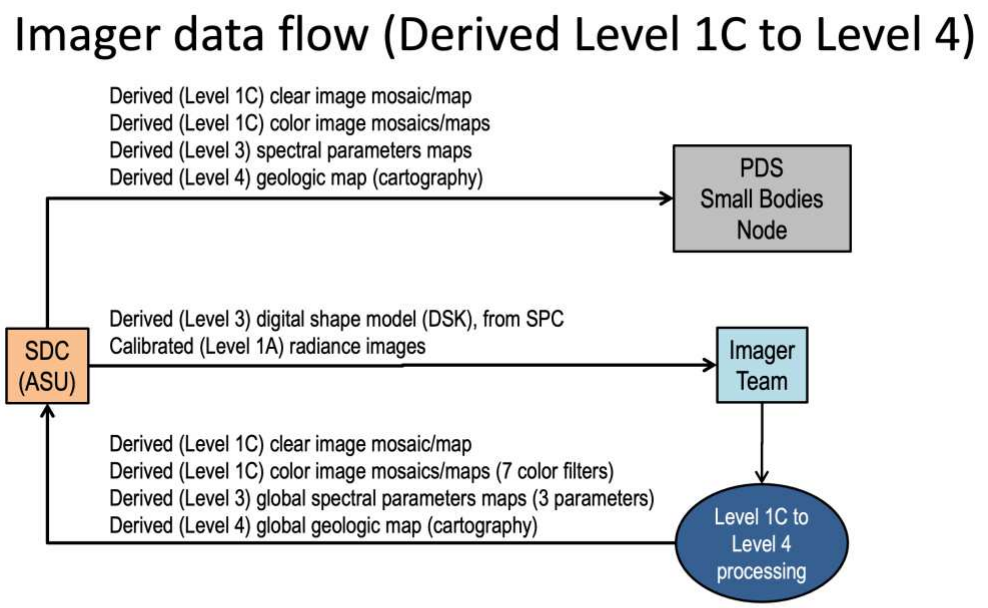

Figure 2–8. The Imager Team generates Derived (Level 2) image mosaics and Derived (Level 3) spectral parameter maps. The Cartography Lead coordinates the mappers to generate the Derived (Level 4) geologic map. Collectively, these products help satisfy Science Objectives 2, 4, and 5.

3 Data rights and release policy

Because of the expected widespread scientific and public interest in Psyche data and the strong project commitment to distributing data on a timely basis, the project has established a clear delivery policy for data archives. A key element of the policy is the need for a reasonable interval of time to generate and validate standard data products before delivery to the general community. Based on numerous past experiences (including the Mars Reconnaissance Orbiter and Dawn projects) and the nature of the Psyche project, three months is deemed necessary to produce useful and accurate Psyche Raw, Partially Processed, and Calibrated data products. The Psyche project begins deliveries of standard data products to the PDS/SBN starting six months after beginning approach to Psyche (which starts 100 days before capture). This is followed by data releases every three months throughout the remainder of the mission. The project goal is to shorten this period if possible. Note that the entire Psyche Science Team has free access to preliminary Level 0–3 products as soon as they are generated, through the SDC.

In addition to producing validated standard data products, public data products (png format) are delivered earlier than the end of the validation period for the former. Raw images will go out to the public in near real-time (~30 minutes) following the initial calibration of the imagers in cruise, using the same standard

JPL process developed for releasing images to the public from the Mars Exploration Rovers, Cassini, Curiosity, and Perseverance.

3.1 Archival data product policies

Specific delivery policies for archival data products are:

1. The generation and validation time period for standard data products is defined to be the period from receipt of raw science input data at the Science Data Center until delivery of data archives to the PDS. The data archives include, as appropriate, standard data products through NASA Level 3, SPICE files, relevant algorithms (or software), and documentation describing how the products were generated. During the generation and validation period, investigation teams are expected to use raw input data (e.g., science and engineering telemetry) to generate standard data products and archives, and to validate the products. Efforts involving all of Psyche's Science Team are expected to be underway during this period, including product validation.
2. Standard data products are listed in Tables 2-3, 4-1, and 4-2. Higher-level products are generated from Raw science data and SPICE data (especially C kernels and SP kernels), at the Psyche SDC and/or lead Co-I facilities. Raw, Partially Processed, and Calibrated data products are generated in a systematic way during the course of the project, by the Psyche investigation science teams. Derived data products are dependent on large amounts of Calibrated data generated over a longer period of time. Thus, they are delivered on a different schedule. During the Psyche mission, increased knowledge of instrument calibrations and operations idiosyncrasies, together with increased knowledge of the Psyche asteroid and better understanding of how to process Raw, Partially Processed, and Calibrated data, is expected to result in updates to some standard data products.
3. Raw, Partially Processed, and Calibrated science data products typically require up to three months to generate and validate, from the time of receipt of raw data at the SDC, to delivery of PDS4-compatible products back to the SDC. The product delivery schedule described in §6 accommodates this. The SDC delivers the first archives to the PDS/SBN seven months after launch (after initial checkout has completed). The SDC delivers the first archives from (16) Psyche six months after the spacecraft begins Psyche approach (which is 100 days before it enters Orbit A at Psyche), and at three-month intervals thereafter. These products are generated by means of configuration-controlled pipelines, which reduces the need for individual PDS review of each delivery. See §6.5 for details of the pipeline review process.
4. Raw data products contain all the necessary input data required to generate Calibrated data products, when used with archived calibration files. (Note that for Magnetometer, this is true for both Partially Processed and Calibrated data.) Relevant instrument engineering data are packaged with the science data. Some relevant spacecraft engineering data (temperatures, voltages, actuator angles, etc.) are included in the Raw (Level 0) products or captured in PDS labels for those data product files.
5. After liens identified during peer review are addressed, the data are archived and the SBN makes them available to the general science community. Assuming the liens are minor as judged by the peer review panel, the data are "certified" and immediately released to the public in advance of liens resolution, suitable for inclusion in NASA data analysis and other proposals.
6. Derived products require longer to generate and validate than Raw, Partially Processed, and Calibrated data. These products include the asteroid digital terrain model (i.e., topographic map), multispectral image mosaics, spectral feature and elemental composition maps, and gravitational and magnetic field models. The delivery schedule for these products is described in §6. Following the required generation and validation period, the relevant higher-level data product collections are transferred to the PDS for peer review. After liens identified during peer review are addressed, the PDS/SBN makes the data available to the general science community as fully validated, certified products.

7. Standard data products are delivered to the SBN in PDS4-compatible format, including all labels and documentation. The documentation shall be thorough enough to understand quantitatively the processing history.
8. Initial shape and gravity models are developed by the Psyche Navigation Team for the purpose of planning future orbits and trajectories. These are generated at the end of each orbit phase. They are not treated as science data products and therefore lie outside of the scope of this document. Note that the Gravity science team generates science-oriented gravity and shape models, that will be delivered to SDC and the SBN and NAIF nodes.
9. Calibration data for all instruments are archived. These include data from laboratory calibration (including derived data products and pre-delivery calibration reports) and Raw Level 0 data from spacecraft level I&T, cruise, and the Mars gravity assist flyby.

The policies listed above pertain to nominal project operations. In the event of significant anomalies, data are archived using these stated policies unless observational, personnel, and/or financial constraints force the need for a longer period between data receipt and transfer of archives to the PDS, as negotiated by the Psyche project, the PDS, and NASA Headquarters.

3.2 Public Data Product Policies

Public information distribution includes press conferences, data made available on the web and via social media, and written materials concerning project operations and/or scientific analyses. Specific policy statements for delivery of public data products for the Psyche project are:

1. The Planetary Division of the Science Mission Directorate (PSD) recognizes the unique contribution its data, discoveries, content, and experts make towards the Nation's science literacy. PSD has the stories to share and engage, and has refocused its approach toward science communications to help its scientists and engineers and communication professionals better contribute towards the public's increased understanding of science and technology, i.e., science literacy. In keeping with this policy, the Psyche mission proposes to make available unprocessed and uncalibrated (or "raw") images, in png format, from the Psyche Imager to the public for them to use and enjoy. Psyche provides the data and subject matter expertise while the public provides the inspiration for all to enjoy.
2. Only NASA Headquarters (in coordination with Psyche project management and the PI) may distribute information to the media and/or the public about spacecraft and instrument anomalies.
3. Information concerning significant scientific results may be distributed during press conferences, press releases, and on the Internet, in coordination with the PI, NASA Headquarters, and the Psyche Science Team.
4. Psyche science results are reported in the peer-reviewed literature following general science conferences on a schedule negotiated by the PI before the start of orbital operations. These conferences may be coordinated with the annual Fall meetings of the American Geophysical Union, the annual meetings of the Division of Planetary Sciences of the American Astronomical Society, and the annual Lunar and Planetary Science Conferences.

3.3 Data Acknowledgement Policy

In any publication or posting of Psyche data or information, appropriate credit is given to all entities involved, including the Co-I (as appropriate – produced and published by Co-I), the Co-I's national space agency and home institution, the PI, the PI's home institution, the Psyche project, and NASA. The credit appears on public web sites that contain data releases and on documentation that accompanies the data products.

4 The Psyche Archive

4.1 Archive contents

The tables and figures in §2 describe the science data products that are generated by the Psyche Science Team. Here we list the data and information used to generate the archived data products. The lists include the instrument science data streams [flight software (FSW) data product files – see below], instrument engineering data (ECSV), some spacecraft engineering data (ECSV), some pre-launch calibration data, calibration files based on pre-launch and in-flight calibration, algorithm/software descriptions in Software Interface Specification (SIS) documents, and some models. Science data packets coming from the spacecraft are reformatted by the GDS into files with a CFDP-like structure, but without header data in the files; metadata are provided in separate metadata files. Engineering data packets are also converted into enhanced character separated values (ECSV) files.

Raw data consist of time-ordered packetized telemetry, or the equivalent, received from the spacecraft, with duplications removed, together with ancillary information needed to understand what is contained in a given packet. Raw instrument science data are provided in the form of data product files (containing instrument data packets) generated by Psyche flight software. For simplicity, these are referred to as “FSW data products” in this document.

Note that each of the teams have access to all of the instrument-relevant and asteroid-relevant SPICE kernel files on the FEI server in the Psyche GDS, not only the files listed below.

4.1.1 Magnetometer

All magnetometer science data products (Raw, Partially-Processed, Calibrated, and Derived) listed in Tables 2-3 and 4-1 are archived. Note that this includes data taken in interplanetary cruise and the flyby of Mars.

Magnetometry Investigation Lead Benjamin Weiss, Instrument Scientist Jodie Ream, and Investigation Scientist Rona Oran at MIT are responsible for generating the Raw (Level 0), Partially-Processed (Level 1A), Calibrated (Level 1B), Derived (Level 2), and Derived (Level 3) data products. Benjamin Weiss, Jodie Ream, Rona Oran, and Jose Merayo (DTU) are responsible for developing and maintaining the algorithms and pipelines that generate all data products.

INPUTS:

The science phase flight data inputs for magnetometer data processing include:

- magnetometer science data (packets in FSW data products), and
- a subset of spacecraft engineering telemetry (CSV files), especially data describing
  - on/off status of various instruments
  - motions of spacecraft subsystems
  - operating status for the electric propulsion thruster and the cold gas thrusters
  - any motors and electromagnetic valves on spacecraft
  - any nearby heaters
  - the momentum wheels
  - the current in solar panels and other aspects of the power management system (cabling, terminal board, shunting),
- spacecraft trajectory data (SPK files), and
- spacecraft attitude data (CK files).

Other inputs that are used for routine magnetometer data processing are:

- laboratory magnetometer calibration data,
- in-flight data from interplanetary cruise, for near-zero-field calibration (and science),
- in-flight data for solar array magnetic field calibration,
- in-flight data from initial check out,
- models of the solar wind, and
- hybrid simulations of the magnetic field environment around Psyche.

The MAG team receives the FSW data products (files) that contain the raw magnetometer telemetry packets. All data processing is carried out at MIT.

OUTPUTS:

The Magnetometer team generates five products, including:

- Raw (Level 0) magnetic field components (B1,B2,B3) for each of the two Sensor Unit (SU)-Electronics Unit (EU) pairs, MAG2 (inboard) and MAG1 (outboard)
- Partially-Processed (Level 1A) magnetic field vectors (B_x, B_y, B_z), for each of MAG2 and MAG1 (time series in nanoteslas),
- Calibrated (Level 1B) magnetic field vectors (B_x, B_y, B_z), corrected for instrument and spacecraft field (time series in nanoteslas),
- Derived (Level 2) corrected magnetic field vectors (B_x, B_y, B_z) in J2000, Psyche body-fixed, and Psyche-Solar-Orbit frames,
- a Derived (Level 3) global remanent magnetic field map, continued down to a uniform defined surface, and
- a Derived (Level 3) remanent magnetic field model in the form of a table of the magnetic dipole moment and the internal Gauss (spherical harmonic) coefficients.

Note that the last two are generated only if a remanent magnetic field is discovered.

A Software Interface Specification (SIS) document is archived for the Raw, Partially Processed, Calibrated & Derived (Level 2) products and another for the Derived (Level 3) products (magnetic field map and Gauss coefficients). In addition to describing data formats, these SIS documents provide some information on how the data products are generated. More details on the algorithms used to generate MAG products are published in the open peer-reviewed scientific literature.

4.1.2 Multispectral Imager

All Imager science data products (Raw, Calibrated, and Derived) listed in Tables 2-3 and 4-1 are archived. Note that this includes data taken in interplanetary cruise and the flyby of Mars, which are not counted in this table.

Imager Lead Jim Bell and Imager Operations Lead Michael Walworth are responsible for generating the Raw (Level 0) and Calibrated (Level 1B) archive data products, as well as developing the pipelines that generate them. Jim Bell, Imager Deputy Lead David Williams, and other Co-Is are responsible for developing the algorithms used to generate all levels of the imager data products.

INPUTS:

The science phase flight data inputs for imager data processing include:

- imager science data - processed to binary images (“EDRs”) at JPL,
- imager engineering telemetry (CSV files),
- a subset of spacecraft engineering telemetry (CSV files) - for example temperatures,
- spacecraft trajectory data (SPK files), and

- spacecraft attitude data (CK files).

Three other inputs that are used for routine imager data processing are:

- laboratory radiometric and geometric calibration data,
- in-flight data (dark field and star field images) from interplanetary cruise and at Psyche, and
- other in-flight calibration data (e.g., standard stars, Mars).

The Imager Team transforms the multispectral imager science data, imager engineering telemetry, and relevant spacecraft telemetry into forms that are compatible with heritage software that the imager team already has working at its home institution.

OUTPUTS:

The Imager team generates six products, including:

- Raw (Level 0) binary images,
- Calibrated (Level 1B) radiance images,
- a Derived (Level 2) global clear filter (Filter 1) image maps,
- a Derived (Level 2) global multispectral filter (Filters 2-8) image map,
- Derived (Level 3) spectral parameter maps of (16) Psyche,
- a Derived (Level 3) global topographic map (DTM), and
- a Derived (Level 4) global geologic unit map.

To generate the Derived (Level 2) global image maps, a shape model must be used as input or generated in parallel. The Gravity team uses stereophotoclinometry (SPC) on the Calibrated (Level 1B) images to produce a tessellated plates shape model (a SPICE kernel, DSK Type 2) as well as a DTM that can be used by the Imaging team and the Imaging team may also produce a shape model using stereo-photogrammetry (SPG) on the Calibrated (Level 1B) image stereo pairs to generate a global DTM product. The Imager Team also generates the spectral parameter maps, based on the global multispectral image mosaics generated by the team. At least three spectral parameter maps are planned, each consisting of three “bands” (generally band ratios):

- a pseudo-true color (simulating human vision) map of Psyche,
- a map of spectral parameters related to sulfide mineral (e.g., oldhamite) coverage, and
- a map of spectral parameters related to iron-bearing silicate mineral (e.g., pyroxene) coverage.

All of the above multispectral products are generated based on data acquired in Orbits A, B1, and B2. All are archived in the PDS/SBN.

Note that the Gravity Team also generates a tessellated-plates shape model (a SPICE kernel, DSK Type 2), but using stereo-photoclinometry on the same input Imager data.

The topographic map and geologic maps are described in §4.1.5 below.

A SIS document is archived for all of the Raw & Calibrated products; another for the Derived (Level 2 and Level 3) global clear, multispectral, and spectral parameter mosaics; and a third for the topographic model (DTM). In addition to describing data formats, the SIS documents provide some information on how the data products are generated. More details on the algorithms used to generate Imager products are published in the open peer-reviewed scientific literature.

4.1.3 Gravity Science (Radio Science Subsystem – RSS)

All Gravity science RSS data (the different raw inputs and the Derived products) listed in Tables 2-3 and 4-1 are archived. Note that this includes data taken in interplanetary cruise and the flyby of Mars, which are not counted in this table.

Ryan Park is responsible for generating the Psyche RSS/gravity (Derived Level 3) data products, as well as developing the algorithms and processing pipeline that generate them.

INPUTS:

The science phase flight data inputs for gravity data processing include:

- radio-metric data (TRK-2-34), which includes the basic DSN Doppler and ranging data used to determine gravitational acceleration,
- media calibration data about the Earth's ionosphere and troposphere (TRK-2-23), which is used to correct Doppler data for terrestrial atmospheric effects,
- weather data (TRK-2-24),
- engineering data ("monitor data") on the DSN stations (packets or ECSV files),
- Psyche communications subsystem engineering data (e.g., transmitter temperatures),
- spacecraft mass history file and small forces files,
- a subset of other spacecraft engineering telemetry (CSV files),
- spacecraft attitude data (CK files), and
- some engineering data for the DSN stations.

In their analysis, the Gravity Science Team develops a spacecraft mass history file and a small forces file that are generated from the spacecraft engineering telemetry.

In addition, the Gravity Science Team uses stereophotoclinometry (SPC) software to analyze Psyche's Imager data and generate a tessellated-plates shape model (DSK) for Psyche and extract landmarks (i.e., control points). The landmarks are processed together with the DSN radio data to determine Psyche's gravity field and rotation. The SPC-derived shape model is used to interpret Psyche's interior structure. This is bookkept under SPICE kernels in Figures 4.1 to 4.6 and Tables 4-1 and 4-2, because it is archived in NAIF, along with other Psyche SPICE kernels.

Three other inputs used for routine gravity data processing are:

- laboratory test data for the communications subsystem (frequency offset vs. temperature, beam pattern, etc.),
- in-flight data from interplanetary cruise, and
- other in-flight calibration data.

The SDC acquires the necessary input data from the Psyche GDS at JPL and makes them available to the gravity team. The SDC is not expected to transform these data, because they are already in forms that are compatible with heritage software that the gravity team has working at its home institutions.

OUTPUTS:

The Gravity team generates this product that is archived in the PDS/SBN:

- a Derived (Level 3) gravity model in the form of a table of spherical harmonics coefficients.

The team generates three products that are archived in the PDS NAIF Node:

- Derived (Level 3) spacecraft orbit ephemeris (SPK) files,

- a Derived (Level 3) tessellated-plates shape model (DSK), generated using stereophotoclinometry (SPC) on Imager data, and
- a Derived (Level 3) best-fit rotation state parameter file (PCK).

There will be pointers in the SBN for those Gravity Science Team science data products that reside in the NAIF node.

Note that the Gravity Science Team does not archive any Calibrated (Level 1B) RSS products. They deliver Raw (Level 0) input data (radio-metric and media calibration files) and the Derived (Level 3) products that they generate, for archival. A Software Interface Specification (SIS) document is archived for the Derived gravity field spherical harmonics coefficients product. The multi-mission SISs for the Raw data (e.g., TRK-2-34 and TRK-2-23 SISs) and for the standard multi-mission Derived products (e.g., PCK and DSK SISs) are archived, as are SISs for other Raw products (e.g., spacecraft mass history and small forces files). None are needed for Calibrated products since these are not separately generated and archived. In addition to describing data formats, the SIS documents (especially the Derived product – Spherical Harmonic coefficients SIS) provide some information on how the data products are generated. More details on the algorithms used to generate gravity data products are published in the open peer-reviewed scientific literature.

4.1.4 GRNS (Gamma-Ray and Neutron Spectrometers)

All GRNS science data products (Raw, Calibrated, and Derived) listed in Tables 2-3 and 4-1 are archived. Note that this includes data taken in interplanetary cruise and the flyby of Mars, which are not counted in this table.

David Lawrence, Patrick Peplowski, Tom Prettyman, and Insoo Jun are responsible for algorithm development. Peplowski leads development of the product generation pipeline and Peplowski and Lawrence are responsible for generating the standard products (assisted by Ray Espiritu and operations staff). Tom Prettyman is responsible for generating shape-topography correction products for GRNS. For this purpose, Prettyman will update and apply the validated and certified PDS4 ephemeris-pointing-geometry (EPG) pipeline developed by Dawn.

INPUTS:

The science phase flight data inputs for GRNS data processing include:

- Gamma-Ray Spectrometer (GRS) science data (packets in FSW data products),
- GRS engineering telemetry (packets),
- Neutron Spectrometer (NS) science data (packets in FSW data products),
- NS engineering telemetry (packets),
- a subset of spacecraft engineering telemetry (CSV files)
- spacecraft trajectory data (SPK files),
- spacecraft attitude data (CK files), and
- an asteroid shape model (DSK).

These other inputs are used for routine GRNS data processing:

- pre-instrument-delivery laboratory calibration data, in the form of derived data products and calibration report,
- in-flight data from interplanetary cruise (e.g., ≥72 hours of GRS cruise operations),
- other in-flight calibration data, and
- a particle transport model for simulation and calibration of sensors and the asteroid surface.

The Psyche GRNS retrieves all Raw (Level 0) data (GRNS science data, GRNS engineering telemetry, and relevant spacecraft telemetry) and uses data processing pipelines to produce data products that are compatible with heritage software that the GRNS team already has working at its home institutions. These products are distributed to the science team and are also used to generate the Calibrated (L1) and Derived (L3) data products to the SDC.

OUTPUTS:

The GRNS team generates eight types of products from the Gamma-Ray Spectrometer (GRS), including:

- Raw (Level 0) time series of raw spectrometer counts,
- Raw (Level 0) time series of gamma-ray and neutron events,
- Raw (Level 0) time series of gamma-ray spectra,
- Raw (Level 0) measurements of the health and and status of the GRS instrument,
- Calibrated (Level 1B) time series of gamma-ray spectra (corrected and energy-calibrated),
- Calibrated (Level 1B) measurements of the health and status of the GRS instrument,
- Derived (Level 3) average composition for ≥9 elements, and
- Derived (Level 3) composition maps for Fe, Ni, Si, and K.

The GRNS team generates eight types of products from the Neutron Spectrometer (NS), including:

- Raw (Level 0) time series of raw spectrometer counts,
- Raw (Level 0) time series of neutron spectra
- Raw (Level 0) time series of neutron events
- Raw (Level 0) measurements of the health and status of the NS instrument
- Calibrated (Level 1B) time series of neutron spectra (gain-corrected),
- Calibrated (Level 1B) measurements of the health and status of the NS instrument,
- Derived (Level 3) count rates, and
- Derived (Level 3) composition map.

The GRNS team is archiving separate SIS documents for the GRS and NS. These SIS documents are further divided into a Raw & Calibrated products SIS and a Derived products SIS, for a total of four SISs. In addition to describing data formats, these SIS documents provide some information on how the data products are generated. More details on the algorithms used to generate GRNS products (including high-level descriptions of the particle transport models) will be published in the open peer-reviewed scientific literature.

4.1.5 Topography and Cartography

The Psyche Team generates two global map products from Imager data:

- a topographic map (digital terrain model) of (16) Psyche,
- a geological unit map of (16) Psyche.

The maps use ortho-image mosaics (clear and multispectral image maps – see §4.1.2 above) as a base maps. The coordinate system and reference frame used for the image mosaics and cartographic products (and other Psyche data products) are generated by the cartographic team, with agreement from the science and instrument teams. Descriptions of these will be included in a later version of this SDMP.

A group of Psyche team members, led by the gravity science investigation, is responsible for generating the global digital terrain model (DTM), using stereophotoclinometry (SPC), from the Calibrated (Level 1B) stereo images generated by the Imager Team (see §4.1.3 above).

The Cartography Lead, David Williams, is responsible for delivering the geologic unit map (a Derived product).

A SIS document is archived for each of these cartographic products. In addition to describing data formats, these SIS documents provide some information on how the data products are generated.

The cartographic products described here, as well as the final Derived (Level 2) image maps described previously, use the coordinate system to be developed for asteroid (16) Psyche. That coordinate system follows International Astronomical Union (IAU) guidelines. Details about Psyche cartographic products and the coordinate system will be provided with the products themselves and include:

- Coordinate frames, constants, and conventions proposed to be used, created, or estimated;
- Estimates of the completeness of coverage, positional accuracy and precision, the accuracy and precision of the mapped parameters, and how the precision and accuracy of the final products is proposed to be determined and made available;
- The proposed generation of any radiometric and geometric calibration data required; and
- Naming conventions and nomenclature.

4.1.6 SPICE Files

SPICE is an acronym used to describe a suite of ancillary data, commonly called kernels:

S Spacecraft Ephemeris, with files containing spacecraft location as a function of time

P Planetary and Satellite ephemerides and associated target body physical and cartographic constants

I Instrument information, including mounting alignment and field-of-view size, shape, and orientation

C Orientation of a spacecraft's primary coordinate systems and possibly angular rates as well

E Event information, including nominal sequences, real-time commanding, unscheduled events, and experimenter's notebook comments (deprecated)

The Psyche flight operations teams generate most SPICE kernels with some instrument information obtained from instrument science teams. There are both predict and reconstructed SPICE files. Reconstructed SPICE kernels are typically generated within two weeks of data acquisition and made available to instrument and science investigation teams. SPICE kernels are used together with a toolkit of software modules (available from the NAIF Node) to generate the derived ancillary data. PDS/SBN organizes and hosts the SPICE peer review in cooperation with NAIF. E kernels will not be developed or used because these are no longer used by most projects. Instead, the as-flown Psyche Science Plan and Psyche Mission Plan will be archived within 6 months after end of mission.

4.1.7 Engineering and Other Data

Engineering data, while not strictly science data, are used to interpret and process science data. Therefore, relevant engineering telemetry are incorporated in the Raw, Partially Processed, and Calibrated (Levels 0-1B) standard data products and thereby archived by the Psyche science investigation teams. Sufficient engineering and housekeeping data are incorporated in the lower level data products (or in some cases archived separately) to permit the science community to generate higher-order Derived (Levels 2 and 3) data products. These data are listed in §4.1.1–§4.1.4, as flight data inputs for science data processing. Additional engineering data may be archived on a best effort basis.

It is understood that International Traffic in Arms (ITAR)-controlled data cannot be accepted by PDS. Delivered data products will be reviewed for ITAR compliance before delivery.

4.1.8 Documentation

Documenting data acquisition and processing histories is crucial to successful long-term use of Psyche data. Information on spacecraft events that affected the sequences and data products are also included.

Information needed to fully understand Raw (Level 0) data, SPICE files, and higher-level products are also generated for long-term use of Psyche data. Documentation to be provided to the Psyche Project and the PDS by each investigation team typically includes:

- Calibration requirements
- Pre-flight calibration reports
- In-flight calibration reports
- User guides that describe data products from particular instruments (and gravity science) and how they were generated
- Software user guides that describe processing software delivered as part of the archive

In addition, the Psyche Project provides:

- Final, as-flown Mission Plan and Science Plan, which includes detailed description of the mission, spacecraft, and instruments.

The Project Office is responsible for providing the archive documents describing the mission and spacecraft, and Psyche investigation teams are responsible for providing the archive documents describing the instruments. These documents (generally PDF files) are included in the archive in the main mission bundle and are cited in the PDS4 Context objects which identify the mission, spacecraft, and instruments. In some cases, it may be necessary to provide links to published papers, instead of full PDFs.

4.2 Archive Structure

Each investigation team archives a bundle consisting of several collections. (Note that the GRNS team archives two bundles.) See Table 4-1 and Figures 4-1 through 4-7. There is a separate collection for each type of science data product. Note that the bundle designs implied by the table and figures are notional and Instrument Bundle documentation (as generated by the teams) is authoritative for actual collections and layout. Each team archives a collection of calibration files and/or parameters that are used in generating those products. Each team archives a collection of documents (which include SISs) and a collection of browse products, if any. The collection of publications (generally links to avoid copyright issues) from each team is archived as part of the Psyche mission's Documents bundle.

The data volumes in Table 4-1 include data from all segments of the mission listed in Table 2-3, but not from the operations margin at the end of Orbit B2 operations. Calculations of data volumes for radio-metric tracking data are based on the DSN support requirements calculated during Phase A.

The Project archives a mission bundle, consisting of documents that are not instrument specific, such as mission and spacecraft description, mission data dictionary, and possibly secondary instances of context objects (primary instances reside in PDS Engineering Node context bundle). Publications by the Psyche science team are also included in the mission bundle.

The bundles described here are finally assembled by the SDC, under the direction of the SDC lead and the Psyche Mission Archive Scientist, based on inputs from the investigation teams and the project.

The bundle design shown below is consistent with PDS requirements as found in Sections 8 and 9 of the PDS Data Provider's Handbook.

Details in the archive structure shown below may change. In particular, it is possible that some higher-level products based on Imager data may reside in a different bundle(s).

Note that the Derived (Level 3) Tessellated plates shape model (DSK file) that is based on SPC is delivered as a SPICE kernel by the Gravity Team, even though it is generated using data from the Imager. This is because it is generated by the Gravity Team and is necessary for interpreting the gravity data.

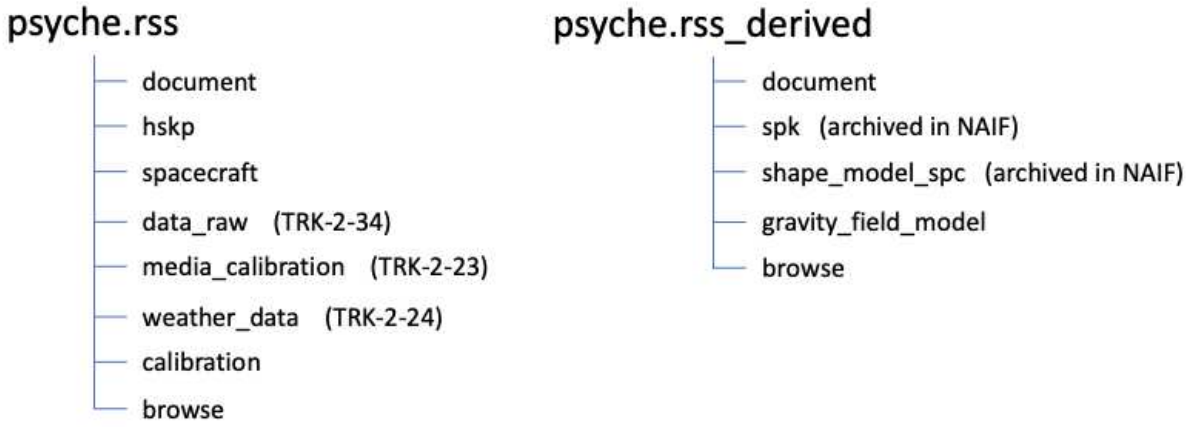

Figure 4–1. The Gravity Science Team archives two Radio Science bundles, one for lower-level products and one for higher-level Derived data products. SPK and Shape Model collections are archived in NAIF (see below). Multi-mission names for Raw (Level 0) products are shown.

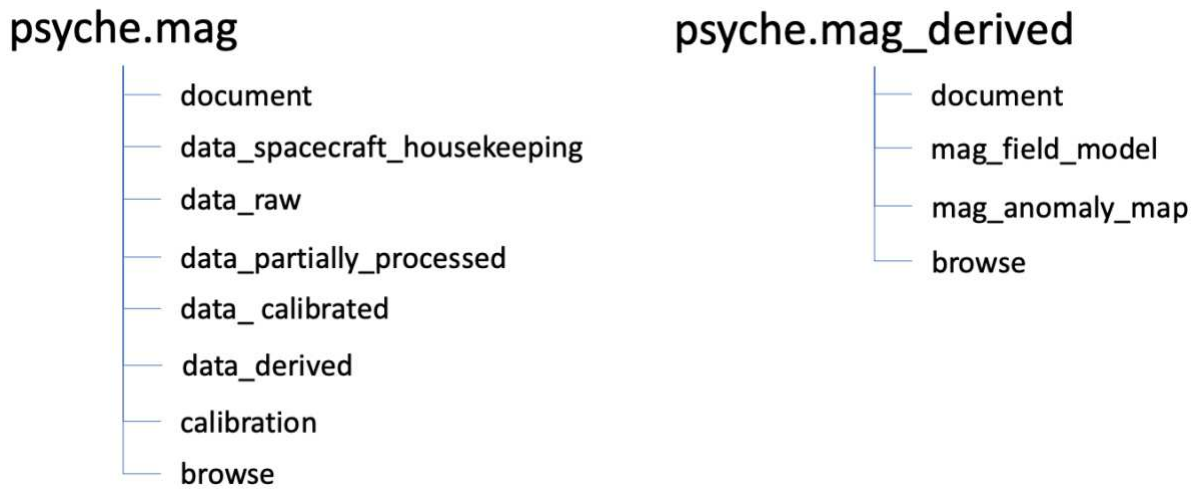

Figure 4–2. The Magnetometer Team archives two bundles, one for lower-level products and one for higher-level Derived data products.

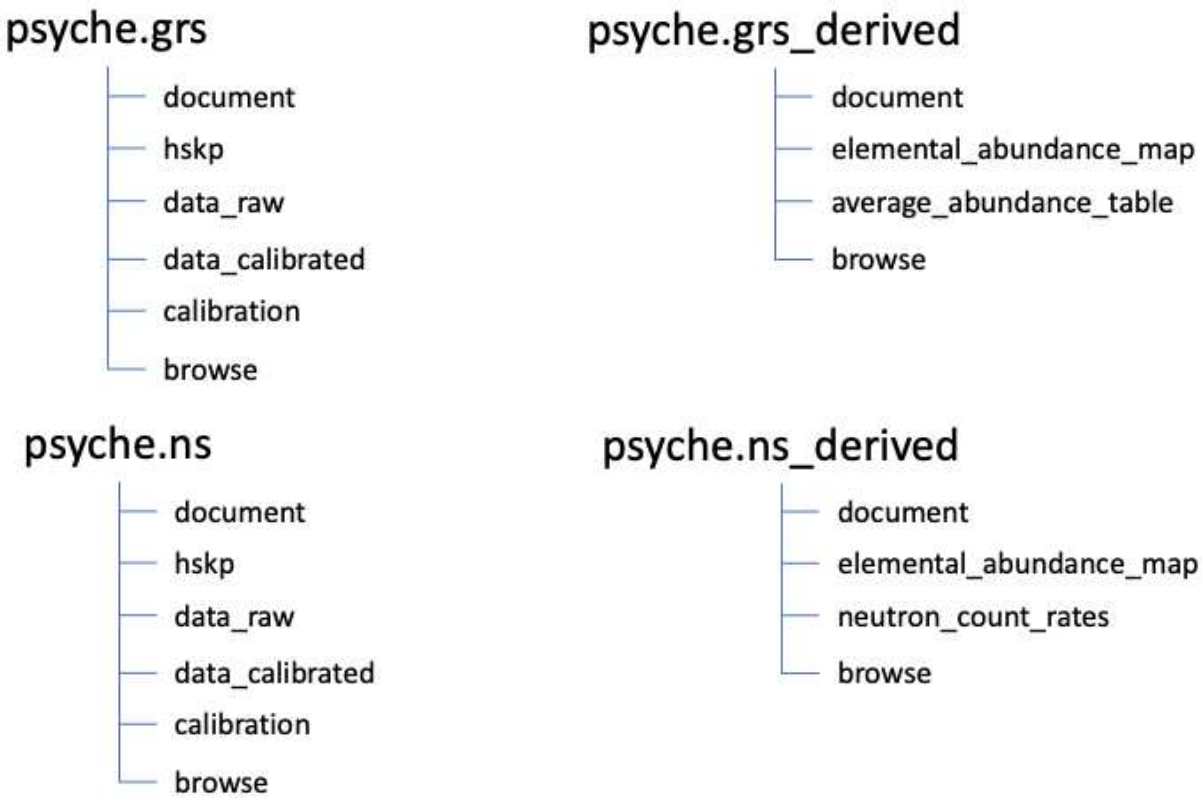

Figure 4–3. The GRNS Team archives two bundles for the neutron spectrometer (one for lower-level products and one for higher-level Derived data products) and two similar bundles for the gamma-ray spectrometer.

Figure 4–4. The Imager Team archives two bundles, one for lower-level products and one for higher-level Derived data products.

Figure 4–5. The Imager Team archives one bundle of Derived (Levels 3 and 4) products generated from analysis of Imager Calibrated (Level 1B) products. Note that the SPG topography map may be provided on a best efforts basis.

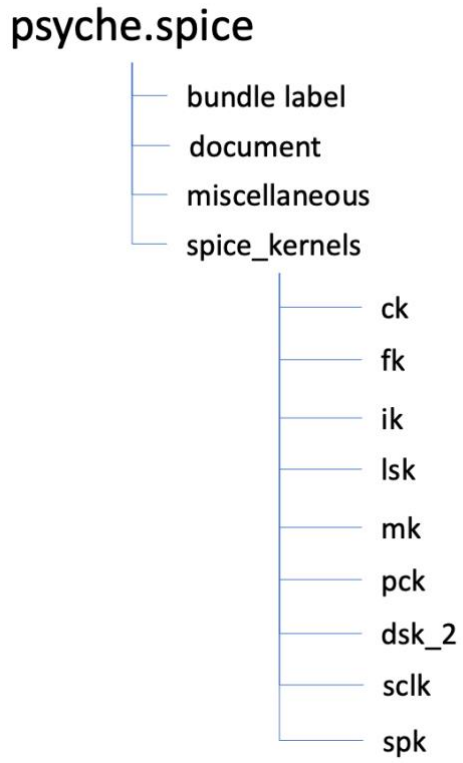

Figure 4–6. Psyche SPICE PDS4 archive will be created using the NAIF-PDS4-BUNDLER (NPB) package and will have the same structure as other SPICE PDS4 archives.

Figure 4–7. The Psyche Project Team archives six mission data collections that provide information on the project and support the other Psyche bundles.

Table 4–1. Psyche's 4 science investigations archive 11 bundles containing 60 collections.

Bundle	Collections	Products	File Size	Data volume
Magnetometer	Raw (L0) Time-stamped, raw orthogonal field components	1 file/day/sensor (total 2 files/day)	340 MB	2470.44 GB
	Partially-processed (L1A) Time series of calibrated magnetic field	1 file/day/sensor (total 2 files/day)	340 MB	1897.2 GB
	Calibrated (L1B) Time series of magnetic field (s/c signature removed)	1 file/day	270 MB	753.3 GB
	Derived (L2) Magnetic field in J2000, etc. coordinates	1 file/day	16 MB	44.64 GB
	Housekeeping (selected spacecraft housekeeping) data	TBD		TBD
	Calibration files	3 files		TBD
	Documents	L0/L1A/1B/L2 SIS, processing description, etc.		TBD
	Browse	TBD		TBD
Magnetometer-derived	Derived (L3) Spherical harmonic coefficients (including dipole moment)	1 file	10 kB	10 kB
	Derived (L3) Magnetic field map	1 file	1 GB	1 GB
	Documents	L3 SIS, processing description, etc.		TBD
	Browse image(s)	TBD		TBD
Imager	Raw (L0) Raw binary images (all images for all filters)	1 file/image (compressed)	4.0 MB	1198.8 GB
	Calibrated (L1B) radiance & IoF images (all images for all filters)	2 files/image	4.0 MB	2397.5 GB
	Housekeeping (instrument & selected spacecraft) data	CSV files	1.2 MB	3.6 GB
	Calibration files	Pre-launch, cruise		34.0 GB
	Documents	L0/L1B SIS, processing description, etc.		12 MB
	Browse images	1 PNG/image; 1 PNG/global-map; 1 PNG/quadrangle		300 GB
Imager-derived	Derived (L2) Global clear filter map at ≤ 20 m/pixel	1 file/quadrangle		20.4 GB
	Derived (L2) Global multispectral image maps at ≤ 200 m/pixel (for filters used in sulfide mineral detection) or ≤ 500 m/pixel (for filters used for iron-bearing silicate mineral detection)	1 file/quadrangle/filter	20.4 GB/filter	163.2 GB
	Derived (L3) Global spectral parameter maps (3 parameters)	1 file/quadrangle/parameter	*1.95 GB/param*	*5.9 GB*
	Documents	L2/L3 SIS, processing description, etc.		12 MB
	Browse images	1 PNG/image; 1 PNG/global-map; 1 PNG/quadrangle	TBD	TBD
Cartography	Derived (L4) Global geologic unit map	1 file (with option for regional maps in other files)		3 GB
	Documents	SISs, processing descriptions, etc.		
	Browse	TBD		TBD
GRS	Raw (L0) Time series of raw GRS counts	1 file/day	5 MB – 152 MB	21.4 GB
	Calibrated (L1B) Time series of corrected calibrated gamma-ray spectra	1 file/day	5 MB – 152 MB	21.4 GB
	Instrument Housekeeping data	1 file/day	2.7 MB	1.5 GB
	Calibration files and geometry correction factors	Pre-launch, cruise, Orbits A&B	50 MB	<5 GB
	Documents	L0/L1B SIS, processing description, etc.		<10 MB
	Browse	1 file/mission-phase		<10 MB
GRS-derived	Derived (L3) elemental abundance map	1 file		<10 MB
	Derived (L3) Fe, Ni, Si, K, S, Al, Ca, Th, U average abundances	1 file		
	Documents	L3 SIS, processing description, etc.		TBD
	Browse image(s)	1 file/mission-phase		<10 MB
NS	Raw (L0) Time series of raw NS counts	1 file/day	1 MB – 5 MB	7.4 GB
	Calibrated (L1B) Time series of corrected calibrated neutron spectra	1 file/day	1 MB – 5 MB	7.4 GB
	Instrument Housekeeping data	1 file/day	2.0 MB	1.1 GB
	Calibration files and geometry correction factors	Pre-launch, cruise	2.0 MB	<500 MB
	Documents	L0/L1B SIS, processing description, etc.		TBD
NS-derived	Derived (L3) elemental abundance map	1 file		<10 MB
	Derived (L3) neutron count rates	1 file/day	<1 MB	TBD
	Documents	L3 SIS, processing description, etc.		TBD

Bundle	Collections	Products	File Size	Data volume
	Browse	1 file/mission-phase		<10 MB
Radio Science (RSS)	Raw (L0) Raw Radio Metric Tracking Data (TRK-2-34)	1 file/pass	75 MB	43 GB
	Raw (L0) Media Calibration File (TRK-2-23)	1 file/month - ionosphere; 1 file/month - troposphere	500 kB total	6.7 MB
	Raw (L0) Weather Data File (TRK-2-24)	1 file/month	<1 MB	TBD
	Raw (L0) Spacecraft Mass History File	1 file	<1 MB	<1 MB
	Raw (L0) Spacecraft Small-Forces File	1 file/orbit-phase	<10 MB	67 MB
	Housekeeping (selected spacecraft) data	TBD	TBD	TBD
	Calibration files	Pre-launch, cruise		TBD
	Documents	TRK-2-34, TRK-2-23, SPK, L0 s/c data file SISs	varies	TBD
	Browse	TBD	TBD	TBD
RSS-derived	Derived (L3) Gravity field spherical harmonic coefficients	1 file	<1 MB	<1 MB
	Derived (L3) Spacecraft ephemeris (SPK file) [*archived in NAIF*]	1 file per orbit phase (A, B, C, and D)	varies	<1 GB
	Derived (L3) Tessellated plates shape model, derived by SPC (DSK) [*archived in NAIF*]	3 files (DSK files) with different resolution (icq128, 256, 512)		<1 GB
	Documents	L3 gravity field SIS, processing description, etc.	varies	TBD
	Browse	TBD	TBD	TBD

Table 4–2. The Psyche Project archives two bundles containing 14 collections. (SPICE kernels volumes based on Dawn experience.)

Bundle	Collections	Products	File Size	Data volume
Mission	Psyche publications	TBD	varies	TBD
	Psyche Science Plan	1 file	TBD	TBD
	Psyche Mission Plan	1 file	TBD	TBD
	Context	1 file		
	XML_Schema	1 file		
	Calibration reports, user guides, mission descriptions, etc.	TBD	varies	TBD
SPICE Kernels	Spacecraft frames kernel (FK)	a few files	varies	<1 MB
	Instrument kernel (IK) files	a few files	varies	<1 MB
	Reconstructed trajectory (SPK) files (& some predicts to fill gaps)	~1 file/month	varies	few GB
	Gravity-team-derived trajectory (SPK) files	1 file per orbit phase (A, B1, D, C, and B2)	varies	few GB
	Reconstructed attitude (CK) files (& some predicts to fill gaps)	~1 file/week	varies	few 10s of GB
	Spacecraft clock (SCLK) files	1 file/release	varies	<1 MB
	Derived (L3) Asteroid rotation & reference frame parameters (PCK file)	a few files	100 kB	<1 MB
	Derived (L3) Tessellated plates shape model, derived by SPC (DSK)	many files	Varies	few 100s of GB

5 Archive generation, validation, and transfer

Standard data products form the core of the archives to be produced by the Psyche project and delivered to the PDS for distribution to the science community. These products, SPICE files, software, documentation (e.g., user guides, tutorials, etc.), and engineering and other ancillary information are validated prior to release. This section discusses the responsibilities, processes, and schedules for generating and validating standard data products and archives by the Psyche project, the PI, and Co-Is.

5.1 Roles and Responsibilities

This section summarizes the roles and responsibilities for personnel and organizations involved in Psyche archive generation, validation, transfer, and distribution.

5.1.1 Project Responsibilities

The Psyche project has overall responsibility for generating and validating archives for release to the PDS. The project is also responsible for distribution of data and associated information to Psyche personnel.

The PI, working with the DAWG Chair, provides oversight of the archiving process. The PI and the DAWG review data analysis plans to ensure timely and adequate analysis of spacecraft data and delivery of documented, complete data to the PDS. They are responsible for the administrative management of data archive planning and implementation.

5.1.2 Psyche SDC Responsibilities

In addition to the functions performed internally for the Psyche Science Team, the SDC at ASU is responsible for packaging all data products received from the team for delivery to the PDS. This includes verifying that all data products meet PDS4 standards at the product level and building the collections and bundles before delivering the data to the PDS/SBN.

5.1.3 Responsibilities of the Investigation Teams and Science Objective Working Groups

Each Psyche investigation team is responsible for generating its own single-instrument data products (Raw, Partially Processed, Calibrated, and Derived). These are delivered to the SDC in PDS4-compatible form. Moreover, each investigation team is responsible for working with the SDC and PDS to develop the collection and bundle concept appropriate to each product. In addition to overall project responsibilities for archiving standard data products, each investigation team has its own data archiving lead (different from that investigation's lead Co-I). See Table 2-1 for details. He or she is responsible for generating validated PDS-compatible archives for each of the standard data products, as specified in Tables 2-3 and 4-1. PDS-compatible archives include documentation, algorithms or software for generating derived data products, calibration data and reports, and other supporting materials in addition to science data products.

The science objective working groups are responsible for generating some derived data products (especially various maps), all in PDS4-compatible forms.

5.1.4 Responsibilities of the Science Team and DAWG

The Psyche DAWG coordinates the planning for generation, validation, and release of PDS-compliant archives to the PDS. The DAWG is a subgroup of the Psyche Science Team. The DAWG Chair and Mission Archive Scientist is Daniel Wenkert, who (under the direction of the PI) ensures that archives are planned, validated, and delivered. DAWG membership from the Psyche science team includes the PI, the Project Scientist, the lead Co-I for each investigation (three instruments plus Gravity Science), the Data Archiving Lead for each investigation, and the lead Co-I for each of the Science Objective Teams. They are joined by the Project Science Systems Engineer, representatives from NAIF, and project personnel selected to ensure that Raw products, engineering data sets, and documentation are included in archives. Representative PDS personnel are liaison members of the DAWG. During the active project, the DAWG provides the coordination needed to ensure that archives are assembled, validated, and delivered according to schedule.

The Psyche team is responsible for correcting liens from the PDS standards validation and external peer review.

5.1.5 Planetary Data System (PDS) Responsibilities

The PDS/SBN Asteroid Subnode is the designated point of contact for Psyche on archive-related issues. The PDS is also the interface between Psyche and the NSSDCA. The DAWG works with the PDS to ensure that Psyche archives are compatible with PDS4 standards and formats. Personnel from the SBN, NAIF node, and Engineering node are liaison DAWG Members.

PDS is responsible for distributing and maintaining the Psyche archives for the NASA planetary science community once the final lien-corrected archives have been delivered by the Psyche project.

PDS/SBN is responsible for providing external peer review of the archive deliveries as well as final validation of PDS4 standards compliance.

NASA has designated the SBN to be the repository of Psyche science data. It provides overall coordination of PDS activities for Psyche.

A Data Engineer from the Engineering Node works with the SBN throughout the archive planning, generation, and validation phases.

The PDS NAIF Node archives SPICE data. SBN organizes the SPICE peer review, with the cooperation of NAIF.

5.1.6 NSSDCA Responsibilities

The National Space Science Data Center Archive (NSSDCA) maintains an archive of Psyche data for long-term preservation and for filling large delivery orders to the science community. The PDS delivers at least one copy of each Psyche archive to the NSSDCA. NSSDCA may also provide support for distributing Psyche data to the general public, although this is beyond the domain of this plan.

5.1.7 JPL Media Relations Office Responsibilities

The JPL Media Relations Office is chartered to be the primary point of contact with the public and the media for activities focused at JPL. The overall objective of the Media Relations Office is to maximize the positive impact of information distribution from the project. This office helps organize and implement press releases and press conferences. They facilitate distribution of public data products and other information meant for consumption by the press and public, including video feeds of interviews. The JPL Media

Relations team will work with the relevant members of the Psyche science and instrument teams in the creation and review of publicly-released data products derived from Psyche instrument data.

5.2 Archive Generation

Psyche science data products, enumerated in Tables 2-3 and 4-1, as well as ancillary data, calibration data, documentation, and PDS labels, are generated and assembled by the Psyche SDC into archive bundles ready for review and archiving. The Raw and Calibrated instrument and gravity data products (that are then assembled into collections and bundles by the SDC) are generated using configuration-controlled pipelines at the Lead Investigation Scientists' sites, so that automated deliveries can be archived on a relatively short timescale. Derived products, collections, and bundles are aggregated in the SDC science data processing environment for peer review and archiving.

Navigation and geometry data in the form of SPICE kernels, necessary to interpret the data (e.g., spacecraft ephemeris and attitude records, clock correlation, etc.) are provided as the SPICE bundle component. NAIF generates this bundle, acting as a Psyche project team directly funded by the project.

Other ancillary data (command histories, and spacecraft and instrument housekeeping files) are provided as ancillary bundle components created by SDC. Calibration data are provided, where necessary for instrument and gravity science data. In addition, files documenting the archive components are prepared by the SDC. In general, all information necessary to interpret and use the data are included in the archive.

The mission bundle and its contents, including documents describing the mission, spacecraft, and instruments, the PDS4 mission data dictionary, and any other mission-level information, is also prepared and assembled in the SDC.

5.3 Archive Validation and Peer Review

Data validation falls into three categories, validation of data packets, validation of usefulness of data for scientific purposes, and validation of compliance with PDS archiving standards. The Psyche GDS is responsible for validating the raw data (packets and/or CFDP files) before they are sent to the SDC. The Science Team is responsible for validating that the data are of appropriate coverage areas and of sufficient quality to produce the required data products. The SDC, overseen by the DAWG and Mission Archive Scientist, is responsible for validating that products meet PDS archive standards before delivering them to PDS.

After a delivery of data to PDS, PDS/SBN carries out a formal peer review process that evaluates the data for content, adequacy of documentation, scientific usability, and adherence to PDS archiving standards. The PDS peer review process uses external reviewers (not involved with either PDS or with the project that generated the data) who are active researchers in planetary science fields relating to the data under review. In addition, the review panel includes PDS personnel who confirm PDS archiving standards compliance.

The schedule for deliveries and peer reviews can be found in Tables 6-1 and 6-2.

5.3.1 Pipeline Peer Reviews

For pipeline data products, including Raw, Partially Processed, and Calibrated data from each instrument and Gravity data, the data volumes for archiving are produced by configuration-controlled pipelines. The output of a pipeline undergoes a PDS peer review, and any further changes to the pipeline are monitored by a configuration control board (CCB). After PDS review and acceptance of the pipeline, further deliveries can be accepted and archived by PDS without additional peer review. Only in the case of

significant changes to the pipeline as judged by the PDS representative on the CCB, is additional peer review necessary.

5.3.1.1 Pre-launch Peer Reviews (Preliminary Pipeline Reviews)

Each instrument team will have a pipeline review before launch for their standard data products (at least Raw, Partially Processed, and Calibrated). These Preliminary Pipeline Reviews are intended to confirm that the pipelines are producing valid data products and labels for all data types, using test or pre-launch data, and that the documentation correctly describes the data products. The initial pipeline reviews will cover:

- Examples of data products and labels;
- Real products based on test data (if available); and
- Draft versions of all documents that eventually will go in a bundle.

All of these review items were delivered and initial reviews completed April-August 2022. All identified liens were resolved in late 2022 and early 2023. Data products generated from post-launch checkout data, will provide a test that the teams have successfully retired all liens identified on their pipelines. This means that each team's pipeline(s) must be approved by their Science Lead Co-Investigator by six months after launch.

5.3.1.2 Cruise Phase Peer Reviews (Pipeline Accreditation Reviews)

Pipelines will be reviewed during the year after Mars Gravity Assist (MGA). See Table 6-1. These Pipeline Accreditation Reviews are intended to confirm that the pipelines are producing archivable data products for the cruise and MGA phases and that the configuration management of the pipelines ensures correct generation of data from upcoming phases. Items to be reviewed include the following.

- Actual products (including labels) generated from data acquired during MGA, if such data exist.
    - If there are insufficient surface observations from MGA from any particular instrument to fully review the calibration portion of the pipeline, additional review may be needed with the delivery of the first (16) Psyche data for that instrument. (The raw portion of the pipeline can be reviewed and accredited with non-surface cruise data.)
    - No such review is currently planned for the Gravity investigation, because low-level data products (tracking data, media calibration data, small forces file, etc.) have multi-mission standard forms and are generated by standard multi-mission-type pipelines.
- The pipeline Configuration Management Plan.
    - This includes such information as: what triggers new reviews, how versioning is done, and how the Configuration Control Board operates.
    - This is reviewed by Project and SBN, not science community.
- All other documents relevant to the reviewed data products must be finished and reviewed with the MGA (and/or other early cruise phase) data products.

To enable the Pipeline Accreditation Reviews, all MGA and prior cruise data products must be delivered by 6 months after MGA. The reviews (not including liens resolution) will be completed 4 months later. Liens resolution must be completed and liens-resolved bundles delivered to SBN by 12 months after MGA. Reviews for Raw and Calibrated product pipelines that could not be accredited using early cruise and MGA data will occur when those products become available after arrival at (16) Psyche.

5.3.1.3 Other Pipeline Peer Reviews

An instrument's calibration process (not just calibration parameters) may be updated after a review of the pipeline during post-Mars cruise. This would trigger a delta review with the first delivery of (16) Psyche data using the updated calibration. Such a review would only cover those parts of the pipeline(s) affected by the calibration process. Other delta reviews may become necessary if there is a significant change to a pipeline, but such a review can often be handled by email.

5.3.2 Non-Pipeline Peer Reviews

For one-time deliveries such as Derived data and special products listed below, no pipeline is necessary and the PDS peer review process is applied to the delivered data volumes. In either case, the peer review may result in "liens" which must be resolved before archiving can proceed. The Psyche archive team is responsible for the resolution of the liens. Once peer reviews and liens resolutions are complete, the PDS conducts a final validation and check before the data are archived and released to the public. Note that if the liens are minor, data volumes may be released to the community for use in NASA proposals before liens resolution is complete.

The following data products have been identified for non-pipeline peer reviews.

- Updated (16) Psyche coordinate system. The coordinate system used in the initial (16) Psyche deliveries will need PDS review, which will take place before Psyche arrival (see Table 6-1).
- The updated (16) Psyche coordinate system based on Psyche mission data will be delivered and reviewed by 12 months after operations in Orbit B1 have concluded.
- SPICE data products, to be delivered to NAIF with the first delivery of (16) Psyche data products and reviewed at that time, six months after the end of Orbit A operations.
- Radio science / Gravity Raw (Level 0) data products will be reviewed after the first delivery of these products (i.e. six months after beginning of Psyche approach, see above). Note that these products are generated by a standard multi-mission pipeline for gravity science investigations. They are not generated by a Psyche pipeline.
- Cartography and Imager Derived data products. The first preliminary deliveries of these would be 6 months after the end of Orbit B1 operations. Preliminary reviews of Imager-based Derived (L2 through L4) products will finish by three months later. Final reviews will occur after final delivery following Orbit B2. See Table 6-2.
- GRNS, Magnetometer, and Gravity Science higher-level data products. Preliminary deliveries are expected approximately 6 months after the start of Orbit C operations. However, formal final deliveries will wait until the end of Orbit B2 operations and end of mission. See Table 6-2 below.

5.4 Archive Transfer

Each investigation team is responsible for delivering standard data products to the SDC in a form that is either compatible with their heritage software or (preferably) PDS4 compatible. The SDC is responsible for converting products to PDS4 compatible products (or ensuring that they are already in such form) and delivering bundles to the SBN. It is currently assumed that all transfers are accomplished electronically. Each bundle will be registered in the PDS4 Registry/Repository. SBN will also transfer Archive Bundles to NSSDCA.

6 Schedule

See Tables 6-1 and 6-2 below for the:

- delivery schedule for data products from the cruise phase.
- delivery schedule for data products from the science phase (Approach through Orbit B2);

Note that there were no deliveries in pre-launch Phase B or Phase C, except updates to this Science Data Management Plan associated with various gate reviews (PDR, CDR, ORR) and draft SISs at the CDR.

6.1 Raw, Partially Processed, and Calibrated Data Product Deliveries

Three months' worth of Psyche Raw, Partially Processed, and Calibrated standard data products are delivered by the SDC to the PDS for review and archiving at three-month intervals. This starts six months after the mission begins the approach phase (which begins 100 days before the spacecraft arrives in Orbit A at (16) Psyche). Following the initial release of data from (16) Psyche, Raw, Partially Processed, and Calibrated data products are delivered to the PDS as part of a single release every three months. In other words, every three months, at time T, the Psyche SDC delivers to SBN all Raw, Partially Processed, and Calibrated standard products generated from data collected between time T-6 months and time T-3 months.

During the six-month period before PDS delivery, these products are generated by the pipelines controlled by instrument Co-Is, delivered to the SDC, and used and reviewed by other members of the overall Psyche Science Team.

Based on reviews and validations of Psyche data processing pipelines, PDS deliveries of lower-level data products from Psyche operations do not require separate PDS peer reviews

Tables with downlink data volumes and Raw, Partially Processed, Calibrated, and Derived data product volumes are found in §2.2 and 4.2 above. There may potentially be some reprocessing of Psyche Calibrated data products. That is not included in the data volume calculations, because the volume of any reprocessing, if it occurs, cannot at present be predicted.

Calibration files, used in generating Calibrated (Level 1B) data products, will be archived with the accompanying early cruise phase data (see cruise phase section below). Any update made during the mission will also be archived with the accompanying Calibrated (Level 1B) data product delivery.

Note that after a new coordinate system is generated using data from orbital operations and is approved, Raw, Partially Processed, and Calibrated products (as well as Magnetometer Derived L2 product see below) will be reprocessed/regenerated and delivered to PDS. The data volume has not been included in the data volume tables, because the size of these deliveries will remain unknown until after Psyche reaches orbit.

6.2 Derived (Levels 2/3/4) Data Product Deliveries

Psyche derived data products can be generated only after global data have been acquired and processed through Calibrated (Level 1B) status. Therefore, Derived (Level 2 and Level 3) data products are delivered on a schedule that is specific to each product.

Magnetometer: Preliminary versions of the Derived (Level 3) products, map and table of coefficients of the remanent field, are delivered to SBN 6 months after the beginning of Orbit C operations. These are based on data collected during Orbits A, B1, and D. Final versions are delivered to SBN 6 months after

the end of Orbit B2 operations (end of mission). This includes 3 months to generate the products and 3 months for the science team to evaluate them internally. The final review and liens resolution will be expedited, based on successful review of the preliminary delivery. Formats and forms of these products should not change between preliminary/initial deliveries after Orbit C and final deliveries after Orbit B2, allowing final review and liens resolution to be expedited.

GRNS: Preliminary versions of the Derived (Level 3) products (maps, neutron count rates, and table of abundances) are delivered to SBN 6 months after the beginning of Orbit C operations. These are based on data collected during Orbits A, B1, and D. Final versions are delivered to SBN 6 months after the end of Orbit B2 operations (end of mission). This includes 3 months for calibration and 3 months for product generation and science team validation. The final review and liens resolution will be expedited, based on successful review of the preliminary delivery. Formats and forms of these products should not change between preliminary/initial deliveries after Orbit C and final deliveries after Orbit B2, allowing final review and liens resolution to be expedited.

Imager and Cartography: The clear and multispectral image maps (ortho-mosaics), topographic map, and spectral parameter maps are all generated based on global imagery acquired in Orbits A, B1, and B2. Initial deliveries of these Derived products (Levels 2 and 3) to SBN are 6 months after the end of Orbit B1 operations. Final deliveries are 6 months after the end of Orbit B2 operations (end of mission). The geologic unit map is based on these Imager data and is delivered to SBN on the same schedule. This map will be published in a peer-reviewed journal (reviewed by at least one geologic mapping expert). Review of its PDS delivery will focus on product quality, readability, and compliance with PDS4 standards. Formats and forms of these products should not change between preliminary/initial deliveries after Orbit B1 and final deliveries after Orbit B2 (although completeness will change). Thus, final review and liens resolution are expected to be expedited.

Gravity: Preliminary versions of the Derived (Level 3) products (table of coefficients, SPK files, tessellated plates shape model, and PCK file) are delivered to SBN 6 months after the beginning of Orbit C operations. These are based on data collected during Orbits A, B1, and D. Final versions are delivered to SBN 6 months after the end of Orbit B2 operations. This includes 3 months to generate the products and 3 months for the science team to evaluate them internally. The final review and liens resolution will be expedited, based on successful review of the preliminary delivery. Formats and forms of these products should not change between preliminary/initial deliveries after Orbit C and final deliveries after Orbit B2, allowing final review and liens resolution to be expedited.

PDS deliveries of these Derived products are each followed by a PDS peer review, liens resolution, and delivery of final liens-resolved bundles to PDS for archiving. The PDS peer review process, including liens resolution, is expected to last approximately three months, so the final delivery of liens-resolved bundles to PDS for archiving can be expected to be complete at 9 months past the end of operations at Orbit B2.

6.3 Cruise Phase Data Product Deliveries

Raw, Partially Processed, and Calibrated data products are generated based on data acquired during interplanetary cruise and the Mars gravity assist (MGA). These products are delivered by the SDC to SBN/PDS on the schedule in Table 6-1. This schedule is tied to launch, MGA, and Approach to (16) Psyche. In each case, between the end of each data collection period and three months later, the products are generated on the Instrument Co-Is pipelines. At that point, the data are generally available to the Psyche Science Team, from the SDC. After validation by the entire team, the SDC delivers the products to the SBN.

The first data collection period starts with launch and includes approximately six months of post-launch instrument checkout data collection. The second period starts there and continues through six months

after the MGA. The third period starts at that point and continues until the beginning of the (16) Psyche approach period (which begins 100 days before arrival in the start of Orbit A).

Pre-launch checkout, characterization, and calibration data are archived with data from the six months of post-launch instrument checkout.

The pipeline accreditation reviews take place during the year after Mars gravity assist (MGA). Interim deliveries of cruise data products before then will get informal reviews. These reviews form part of the validation process for the Psyche data processing pipelines. That validation should reduce the necessity of every-three-months peer review of products generated from data at (16) Psyche.

For the purpose of products generated early in the mission, the science team will use the preliminary Psyche (16) coordinate system based on Shepard et al. (2021). These will be updated after a better coordinate system has been developed from orbital operations at (16) Psyche.

6.4 Document Deliveries

Software Interface Specification (SIS) documents for Raw (Level 0) data products are delivered as needed by each investigation team. The first version is due at the pre-launch Operations Readiness Review. A final version is due at Pipeline Certification Review.

Software Interface Specification (SIS) documents for Partially Processed (Level 1A) and Calibrated (Level 1B) data products are delivered as needed by each investigation team. The first version is due at the pre-launch Operations Readiness Review. A final version is due at Pipeline Certification Review.

Software Interface Specification (SIS) documents for Derived (Levels 2 and 3) data products are due three months before preliminary versions of those products are delivered to SBN/PDS.

This Science Data Management Plan is updated as necessary, throughout Phases B–E. A new version is delivered before each major review (PDR, CDR, and various ORRs).

6.5 Pipeline development and review

Data product design and pipeline development started well in advance of launch. The Psyche Investigation Teams developed their data processing pipelines during Phase D, using data acquired during instrument integration and test as well as spacecraft ATLO. These pipelines were reviewed by peers, including PDS/SBN representatives in the May-August 2022 timeframe.

After launch, there is a peer review covering pipeline output from operations during cruise and Mars gravity assist (MGA), before arrival at (16) Psyche, intended to accredit the pipelines to deliver data which can be archived without additional peer review. This review takes place in the year after MGA (well before (16) Psyche approach). As surface observations are needed to fully accredit the calibration portion of the pipeline, in the case that insufficient surface observations are obtained in the flyby, this portion of the review will be completed using the first delivery of (16) Psyche data. The raw portion of the pipeline can be reviewed and accredited using non-surface cruise data.

6.6 Distribution

Once delivered to the PDS, the Psyche archives are publicly available online through the standard PDS registry and the online search service, as well as via more specialized PDS search and retrieval tools. The user can search for and retrieve data based on criteria such as time range, instrument, or processing level. Map-based searches are also supported as appropriate. Data are available to the public via

electronic transfer. All of this takes advantage of modern, open source, big data infrastructure for search and distribution.

Table 6–1. Reviews and deliveries of pre-arrival products are tied to cruise mission events.

Event	Relative time
Pre-launch review delivery	April-August 2022 (liens resolved by February 2023)
Pipeline approval by instrument lead Co-I after launch (L)	L + 6 months
Cruise Test Delivery to SBN (after initial checkout completed)	L + 7 months, As needed
Mars gravity assist (MGA) Raw through Calibrated products delivery to SBN	MGA + 6 months
Pipeline accreditation reviews for MGA Raw through Calibrated products	MGA + 10 months
Liens resolved for MGA Raw through Calibrated products	MGA + 12 months
Preliminary (16) Psyche coordinate system delivered to SBN for review	(16) Psyche approach - 12 months
Preliminary coordinate system review concluded	(16) Psyche approach - 9 months
Preliminary coordinate system liens resolved	(16) Psyche approach - 7 months
Pipeline delivery of remaining Cruise data to SBN (accredited pipelines)	(16) Psyche approach - 12 months

Table 6–2. Reviews and deliveries of Psyche-orbit products are tied to orbital mission events.

Event	Relative time
Pipeline reviews for Raw – Calibrated products not accredited at prior review	(16) Psyche approach +3 months
First pipeline delivery of (16) Psyche raw through cal products to SDC	(16) Psyche approach +3 months
First pipeline delivery of (16) Psyche raw through cal products to PDS/SBN	(16) Psyche approach +6 months
Subsequent deliveries of (16) Psyche raw through cal products for archiving	Every 3 months
Begin delivery of (16) Psyche SPICE kernels to NAIF	End of (16) Psyche Orbit A operations + 6 months
First delivery of Raw radio science products to SBN for review	Begin Orbit A ops + 6 month

First delivery of Magnetometer Derived Level 2 products to SBN for review	Begin Orbit A ops + 6 months (TBC)
(16) Psyche coordinate system - final update and review (depends on light)	End of Orbit B1 ops + 12 months
Deliver Cartography & Imager Derived products *based on B1 data*	End Orbit B1 ops + 6 months
Finish review of Cartography & Imager Derived products based on B1 data	End Orbit B1 ops + 9 months
Deliver Cartography & Imager Derived products based on B1+B2 operations	End of Orbit B2 operations (EOM) + 6 months
Finish review/liens of Carto & Imager Derived products based on B1+B2	End of Orbit B2 operations (EOM) + 9 months
Deliver *prelim* GRNS, Magnetometer, Gravity highest-level Derived products	Begin Orbit C operations + 6 months
Final delivery of SPICE kernels to NAIF	End of Orbit B2 operations (EOM) + 3 months
Deliver *final* GRNS, Magnetometer, Gravity highest-level Derived products	End of Orbit B2 operations (EOM) + 6 months
Finish review and resolve liens for same (already had prelim review)	End of Orbit B2 operations (EOM) + 9 months

APPENDIX: Current best estimate schedule for Psyche science data product deliveries

These dates are based on the trajectory and orbit plan approved the project and program in January 2023. The dates are subject to change, but will maintain their relative positions as described in Tables 6-1 and 6-2. Table A-1 (see below) is based on the following current best estimate dates for various mission events.

Mission Phase	**Current Best Estimate Start Date (Duration)**
Launch period open	Oct 5, 2023
MGA	May 9, 2026 (will vary based on actual launch date)
Approach	May 9, 2029 (100 days)
Orbit A	Aug 17, 2029 (56 days)
Transfer to Orbit B1	Oct 12, 2029 (17 days)
Orbit B1	Oct 29, 2029 (92 days)
Transfer to Orbit D	Jan 29, 2030 (98 days)
Orbit D	May 7, 2030 (163 days including operations margin)
Transfer to Orbit C	Oct 17, 2030 (90 days)
Orbit C	Jan 15, 2031 (100 days)
Transfer to Orbit B2	Apr 25, 2031 (23 days)
Orbit B2	May 18, 2031 (102 days)
Operations Margin	Aug 28, 2031 (65 days)
End of Mission	Nov 1, 2031

Table A–1. Psyche's 4 science investigations deliver products and bundles with the following schedule. (Reviews in bold.)

Delivery / Review	IOT Start	IOT End	SDC Start	SDC End	Deliver to PDS	Finish Review	Resolve Liens
Pre-Launch review					02/15/22	05/02/22	02/28/23
Lead Co-I approval of pipeline	10/15/23	04/15/24					
Cruise test delivery (preliminary Raw – Calibrated products)	10/15/23	02/15/24	02/15/24	05/15/24	05/15/24		
Deliver Mars Gravity Assist (MGA) Raw – Calibrated, & SPICE products	04/15/26	08/15/26	08/15/26	11/15/26	11/15/26		
Post-MGA pipeline accreditation review					03/15/27	06/15/27	09/15/27
Deliver preliminary Psyche (16) coordinate system					05/09/28	08/09/28	10/09/28
Deliver MGA (update) and full cruise Raw – Calibrated, & SPICE products	10/15/23	02/09/28	02/09/28	05/09/28	05/09/28		
Deliver Raw – Calibrated products not not accredited previously	02/09/28	05/09/29	05/09/29	08/09/29	08/09/29	11/09/29	12/09/29
#1 delivery of Raw – Calibrated, & SPICE products from (16) Psyche	02/09/29	08/09/29	08/09/29	11/09/29	11/09/29		
#2 delivery of Raw – Calibrated, & SPICE products from (16) Psyche					02/09/30		
#3 delivery of Raw – Calibrated, & SPICE products from (16) Psyche					05/09/30		
Continue to deliver Raw – Calibrated, & SPICE products every 3 months					…		
Last routine delivery of Raw – Calibrated, & SPICE products					08/09/31		
Deliver first (16) Psyche Radio Science Raw products	05/09/29	11/17/29	11/17/29	02/17/30	02/17/30	05/17/30	06/17/30
Deliver first (16) Psyche Mag Derived L2 products	05/09/29	11/17/29	11/17/29	02/17/30	02/17/30	05/17/30	06/17/30
Deliver Cartography & Imager Derived products, based on orbit B1	08/17/29	04/29/30	04/29/30	07/29/30	07/29/30	10/29/30	11/29/30
Deliver final Psyche (16) coordinate system					10/29/30	01/29/31	04/29/31
Deliver final SPICE kernels to NAIF	05/09/29	11/26/31	11/26/31	02/26/32	02/26/32		
Deliver to SDS final Cartography & Imager Derived Products	05/09/29	11/26/31	11/26/31	02/26/32	02/26/32	04/26/32	05/26/32
Deliver to SDS final GRNS, Mag, Gravity highest-level Products	05/09/29	11/26/31	11/26/31	02/26/32	02/26/32	04/26/32	05/26/32