Revision: B

Date: September 27, 2021

Parker Solar Probe (PSP)
Science Data Management Plan

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Revision Log

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-	M. Kusterer	Edits in 2.2.3.2, 4.1, 4.1.1, 4.2, 6.2.	09/30/14
	A. Vourlidas	Edits in 2.2.2, 2.2.3.2, 3.2.4.4, 4.1, 4.1.5, Apdx A	08/07/14
	M. Pulupa	Edits in 2.2.3.1, 4.1, 4.1.2, 4.3.1, 4.4.1	08/27/14
	J. Niehof	Edits in 4.1, 4.1.3 and 5.1.2	09/11/14
	K. Korreck	Edits in 2.1, 2.2.3.1, 2.2.3.2, 4.1, 4.1.4, 4.3.3, 4.4.3, 6.2, 6.2.3	08/25/14
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	J. Kasper	Edits in 4.1.4	11/17/14
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	M. Kusterer	Changed ISIS to ISΘIS and SPP to PSP, 3.1, 4.1.2, 4.1.6	3/19/18
	M. Kusterer	Changed 5.1 to update the length of time SSR telemetry files will be stored to match the MOC to SOC ICD	3/19/18
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1 INTRODUCTION

1.1 Purpose

The Parker Solar Probe (PSP) Science Data Management Plan (SDMP) presents a high-level strategy for the generation, validation, and delivery of science data products by each of the PSP instrument suite Science Operation Centers (SOCs). The plan also specifies policies and procedures for distributing data and data products to co-investigators, the wider science community, and the general public. The science planning process is covered in the last section.

1.2 Scope

The plan describes the data processing approach and implementation, data and documentation products, data availability, and storage and archival strategies for the PSP mission. The details of the processing of each data set are found in the respective documentation for that instrument.

Specific aspects addressed in this plan are:

1. Definition of data products (including levels)
2. Definition of documentation products to be provided on datasets, instruments, calibration and algorithms.
3. Identification of publicly disseminated data
4. Method of distribution of data to the public
5. Schedule for making data publicly available.
6. Long term storage and archival plans.
7. Science Planning Process

1.3 Configuration Management

The data contained in this document represent the current definition of the Parker Solar Probe Mission Project Data Management Plan. This document, after formal release, shall be revised only through the formal change control procedures as described in the PSP Configuration Management Plan.

1.4 Applicable Documents and Constraints

Some documentation retains the previous name of Solar Probe Plus (SPP).

1. 7434-9047 SPP Mission Requirements Document (MRD)
2. 7434-9164 SPP Mission Operations Plan
3. 7434-9051 Payload Requirements document
4. 7434-9016 SPP Concept of Operations
5. 7434-9078 SPP Mission Operations Center (MOC) to PSP Science Operations Center (SOC) and Interface Control Document (ICD)
6. 7434-9163 SPP MOC Data Product Document
7. 7434-9140 Mission Archive Plan
8. 7434-9006 SPP Configuration Management Plan
9. NPD 2200.1 Management of NASA Scientific and Technical Information
10. NPR 2200.2B Requirements for Documentation, Approval and Dissemination of NASA Scientific Information
11. NPR 1441.1 Records Retention Schedules
12. Activity Planner – Orbit Activity File Output & Activity File Ingest
13. PSP Science Planning Analysis and Data Estimation Resource (SPADER) User's Guide.
14. 7434-9181 PSP Science Operations Planning Interface Control Document
15. PSP Activity Calendar User Guide

2 PSP PROJECT OVERVIEW

2.1 PSP Mission

The Parker Solar Probe (PSP) mission targets the fundamental processes and dynamics that characterize the Sun's corona and outwardly expanding solar wind and energetic particles.

The mission explores the inner region of the heliosphere in great detail through *in-situ* and remote sensing observations of the magnetic field, plasma, and accelerated particles in that region.

At times of lower solar activity, the solar wind is bimodal, consisting of a dominant quasi-steady high-speed wind that originates in open-field polar coronal holes and a variable, low-speed wind that originates around the equatorial streamer belt. As solar activity increases, this orderly bimodal configuration of the corona and the solar wind breaks down, the polar holes shrink, and streamers appear at higher and higher heliographic latitudes. At these times, the wind structure becomes a complex mixture of fast flows from smaller coronal holes and transients, embedded in a slow-to-moderate-speed wind from all latitudes. The energy that heats the corona and drives the wind ultimately derives from convective motions and is channeled, stored, and dissipated by the magnetic fields that emerge from the photosphere and structure the coronal plasma. Several fundamental plasma physical processes - waves and instabilities, magnetic reconnection, turbulence - operating on a vast range of spatial and temporal scales are believed to play a role in coronal heating and solar wind acceleration.

PSP travels much closer to the Sun (<10 solar radii (R_s) from solar center) than any other spacecraft in order to repeatedly obtain *in-situ* and remotely sensed coronal magnetic field and plasma observations in the region of the Sun that generates the solar wind and ultimately creates space weather. The seven-year prime mission lifetime permits observations to be made over a significant portion of a solar cycle. The direct plasma, magnetic field, and energetic particle observations from PSP will allow testing of and discrimination among the broad range of theories and models that describe the Sun's coronal magnetic field, the heating and acceleration of the solar wind, and the generation, acceleration, and propagation of energetic particles.

2.1.1 Science Objectives

The primary science goal of the Parker Solar Probe mission is to determine the structure and dynamics of the Sun's coronal magnetic field, understand how the solar corona and wind are heated and accelerated, and determine what mechanisms accelerate and transport energetic particles.

The PSP mission will achieve this by identifying and quantifying the basic plasma physical processes at the heart of the Heliosphere. The primary PSP mission science goal defines three overarching science objectives. These objectives with their associated fundamental questions are as follows:

1. Trace the flow of energy that heats and accelerates the solar corona and solar wind.
    a. How is energy from the lower solar atmosphere transferred to, and dissipated in, the corona and solar wind?
    b. What processes shape the nonequilibrium velocity distribution observed throughout the heliosphere?
    c. How do the processes in the corona affect the properties of the solar wind in the heliosphere?

2. Determine the structure and dynamics of the plasma and magnetic fields at the sources of the solar wind.
    a. How does the magnetic field in the solar wind source regions connect to the photosphere and the heliosphere?
    b. Are the sources of the solar wind steady or intermittent?
    c. How do the observed structures in the corona evolve into the solar wind?

3. Explore mechanisms that accelerate and transport energetic particles.
    a. What are the roles of shocks, reconnection, waves, and turbulence in the acceleration of energetic particles?
    b. What are the source populations and physical conditions necessary for energetic particle acceleration?
    c. How are energetic particles transported in the corona and heliosphere?

The PSP spacecraft will fly through the region where the solar wind is accelerated from the Sun, making in-situ measurements and remote observations between <10 solar radii and at least out through 53.5 R_s. Observations outside of 53.5 R_s will include, as a minimum, the measurements that are essential for calibrating observations and validating and interpreting the data collected inside that distance. The perihelion, over the solar equator, must be within the corona so that the spacecraft passes through the location where acceleration processes are theorized to occur. By making direct, *in-situ* measurements of the region where the solar wind is created and where some of the most hazardous solar energetic particles are energized, Parker Solar Probe will make fundamental contributions to our ability to characterize and forecast the dynamics of the heliosphere and its radiation environment, an environment in which future space explorers will live and work.

2.1.2 Science Investigation Summary Description

The five PSP science investigations are summarized below.

Fields Experiment (FIELDS): This investigation will make direct measurements of electric and magnetic fields and waves, Poynting flux, absolute plasma density and electron temperature, spacecraft floating potential and density fluctuations, and radio emissions.

Solar Wind Electrons Alphas and Protons (SWEAP) Investigation: This investigation will count the most abundant particles in the solar wind -- electrons, protons and helium ions -- and measure their properties such as velocity, density, and temperature.

Wide-field Imager for Solar PRobe (WISPR): This telescope will take images of the solar corona and inner heliosphere. The experiment will also provide images of the solar wind, shocks and other structures as they approach and pass the spacecraft. This investigation complements the other instruments on the spacecraft providing direct measurements by imaging the plasma the other instruments sample.

Integrated Science Investigation of the Sun (IS⊙IS): This investigation makes observations of energetic electrons, protons and heavy ions that are accelerated to high energies (10s of keV to ~100 MeV) in the Sun's atmosphere and inner heliosphere, and correlates them with solar wind and coronal structures.

2.2 Mission-Level Science and Data Operations

The PSP Mission will fully support the broader goals of the Heliophysics Data Environment by providing full and open access to various levels of the PSP science data products. During Phase C/D, the Science Working Group (SWG) discussed coordination, cross calibration, and collaboration with other assets and missions and developed a framework for sharing data. The instrument teams will create metadata products to help integrate PSP data into the appropriate NASA Virtual Observatories.

2.2.1 Coordination of Science/data Activities

The PSP project will support the broader heliophysics goals as laid out in the NASA Heliophysics Science Data Management Policy, which is a step forward in the evolution of the Heliophysics Data Environment. The goal of the Heliophysics Data Environment is to enable science discovery where data are efficiently served through active and (longer-term) resident archives.

The PSP mission will provide a Science Gateway – a web-based interface providing a common point of entry of specific interest to PSP scientists as well as the general public. The PSP Science Gateway will provide ancillary services, tools, data and links that benefit the PSP project itself and allow users from the wider heliophysics community to access all PSP data and related products.

The PSP instrument teams will also work with the appropriate virtual observatories (VO) to promote the distribution of their data. The VOs provide a searchable data catalog of distributed space physics data products within a single user interface and allow scientists to access data from many missions from a single "data portal" or even directly from their own software applications

2.2.2 PSP Mission Data Documentation, Model and Tools Availability

The following are NASA policies for mission data documentation and the availability of project funded models and tools.

1. All projects need a Project Data Management Plan.
    a. It will be updated as necessary to provide a record of the mission's archiving practices. It will be worked with HQ and maintained publicly at the NASA archives.
2. All projects need a Calibration and Measurement Algorithm Document.
    a. It will be updated as necessary to provide a guide to how the data are calibrated and the higher-level data products are produced. It will be a project-level document and maintained publicly at the NASA archives.
3. All projects need to produce a plan to move project-funded models/tools to open source distribution.

*: Items 2 and 3 level of funding has to be worked out with NASA in the next year

2.2.3 PSP Mission Rules of the Road for Data Usage

As part of the development of collaboration with the broader Heliophysics community, the mission has drafted a "Rules of the Road" to govern how PSP instrument data is used.

1. The PI of each instrument shall make all scientific data products available to the public, as stated in the PSP Science Data Management Plan.

2. Users are encouraged to consult with the relevant PI or their designates to discuss the appropriate use of instrument data or analysis results and to ensure that the Users are accessing the most recent available versions of the data and analysis routines. Such resources as Investigation SOC Web Sites, the PSP Science Gateway, the NASA CDAWeb, Virtual Solar Observatory and NASA's Heliophysics Data Environment can help facilitate such consultations.

3. Users should heed the caveats of investigators to the interpretation and limitations of data or model results. Investigators supplying data or models may insist that such caveats be published. Data and model version numbers should also be specified.

4. Browse products, Quick-look and Planning data are not intended for science analysis or publication and should not be used for those purposes without consent of the PI.

5. Users should acknowledge the sources of data used in all publications, presentations, and reports.

"Parker Solar Probe was designed, built, and is now operated by the Johns Hopkins Applied Physics Laboratory as part of NASA's Living with a Star (LWS) program (contract NNN06AA01C). Support from the LWS management and technical team has played a critical role in the success of the Parker Solar Probe mission."

Use of any FIELDS data should also contain the following acknowledgement *"Thanks to the FIELDS team for providing data (PI: Stuart D. Bale, UC Berkeley)*".

Use of any IS⊙IS data should include the following acknowledgement and also refer to the publication provided below. “Thanks to the Integrated Science Investigation of the Sun (IS⊙IS) Science Team (PI: David McComas, Princeton University).”

Reference Publication:

McComas, D. J. et al. (2016), Integrated Science Investigation of the Sun (IS⊙IS): Design of the Energetic Particle Investigation, Space Science Reviews, 204, 187–256, doi:10.1007/s11214-014- 0059-1.

Use of any SWEAP data should also contain the following acknowledgement “*Thanks to the Solar Wind Electrons, Alphas, and Protons (SWEAP) team for providing data (PI: Justin Kasper, BWX Technologies).*”

Use of any WISPR data should also contain the following acknowledgment and also refer to the publication provided below. “*The Wide-Field Imager for Parker Solar Probe (WISPR) instrument was designed, built, and is now operated by the US Naval Research Laboratory in collaboration with Johns Hopkins University/Applied Physics Laboratory, California Institute of Technology/Jet Propulsion Laboratory, University of Gottingen, Germany, Centre Spatiale de Liege, Belgium and University of Toulouse/Research Institute in Astrophysics and Planetology.*”

Vourlidas, A. et al. (2016), The Wide-Field Imager for Solar Probe Plus (WISPR), Space Science Reviews, 204, 88–130, 10.1007/s11214-014-0114-y

6. Users are encouraged to provide the PI a copy of each manuscript that uses the PI’s data prior to submission of that manuscript for consideration of publication. On publication the citation should be transmitted to the PI, the mission Project Scientist, and any other providers of data.

2.2.4 Coordination of science/data activities between PSP teams and other Heliophysics missions

Through discussions of the SWG, the PSP Mission will develop methods of collaboration between the instrument teams. Initial coordination between PSP instrument teams include but are not limited to onboard data sharing and onboard event trigger signaling. This coordination will continue to be detailed through Phase C/D.

In addition to the payload data from PSP, the mission will also collaborate with other missions to augment primary data sets. One such mission is Solar Orbiter, which will provide large-scale remote sensing measurements during the encounter phases of the PSP mission. Data from the network of ground-based telescopes will also be used to provide global images of the Sun in multiple wavelengths during the encounter phases.

2.2.3.1 Data Sharing

In order to optimize the science return from the PSP mission, the PSP instruments will coordinate data sharing of their Level-2 through 4 products, which are described in Section 4.

On the ground, there are 3 instances of exchange of data between teams. The first is quicklook data. These data are for planning purposes not for scientific analysis. The second data exchange is for selection of full resolution data periods of interest. The third exchange will occur in order to produce higher-level data products.

Onboard data sharing will occur through the instrument shared data fields in the Spacecraft Time and Status Packet. This message will serve as a way to pass data between the instruments. The details of this message will be in the General Instrument (GI) ICD (7434-9066).

A dedicated on-board data link between FIELDS and SWEAP suite will provide high time-resolution wave-particle correlation data. Details of this dedicated link can be found in SPF_MEP_105_SWEAP_ICD FIELDS-SWEAP Interface Control Document.

Both FIELDS and SWEAP have on-board memory buffers and can prioritize the down-linking of these data by reviewing data products from other teams in addition to their own survey data. This data selection process can utilize supplementary data from other assets both on PSP and elsewhere if the data products are available 7 days before the upload of data transfer commands. The FIELDS and SWEAP teams can prioritize the selection of full resolution data for down-link using their respective data only.

Planning data is described for each instrument suite. FIELDS will provide magnetic field vectors in an inertial coordinate system; frequency vs. time spectrograms showing spectral density of electric and magnetic field fluctuations, covering frequencies up to 64 kHz; Search Coil Magnetometer (SCM) response up to 1 MHz; wave power up to 16 Mhz; start time, duration, and FIELDS configuration for burst intervals. SWEAP will provide ion velocity, density, and temperature quicklook data to the PSP instrument teams for planning purposes. IS⊙IS will provide unvalidated "browse" data to the other PSP instrument teams. The browse data will include count rates at levels spanning the energy range of EPI-Hi and EPI-Lo. WISPR will provide white light images of the solar wind, shocks and other structures to provide context for the in-situ measurements.

There will also be coordination of data product metadata (such as ISTP compliant CDF metadata or FITS keywords) to ensure inter-operability of software and common understanding of definitions, for both PSP instruments and the wider science community. A document detailing these standards will be maintained at the PSP Science Gateway which is described in section 2.2.1.

3 Science Operation Centers

The PSP ground system is comprised of a centralized Mission Operation Center (MOC) and one Science Operation Center (SOC) per instrument suite.

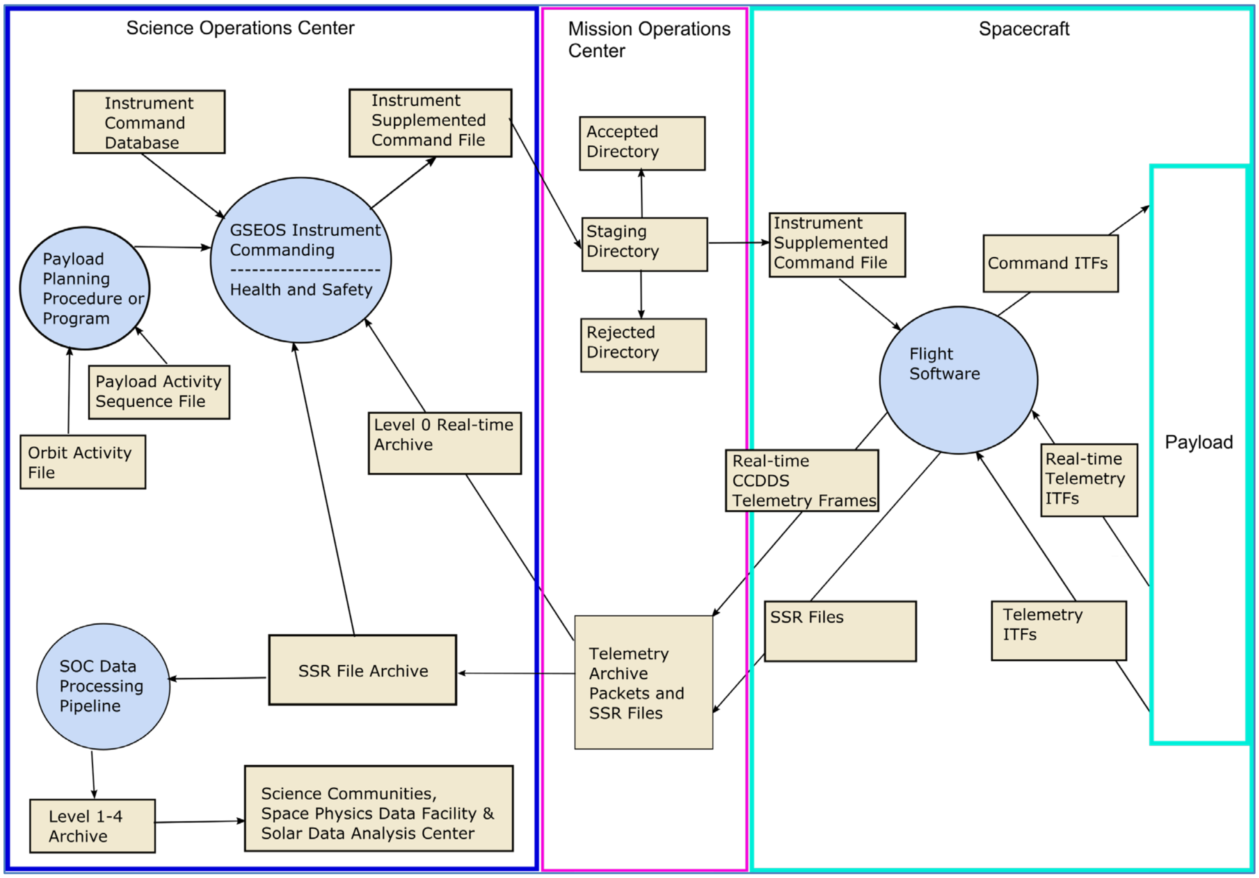

Figure 3.a Science Operations Center, Mission Operations Center and Spacecraft Data Flow.

The top half of figure 3.a describes the data flow from the top left with the output of the planning process, Orbit Activity File and Payload Activity Sequence File to the Payload Planning, generation of instrument commands and their flow through the Mission Operations Center (MOC) to the spacecraft and then to the instrument on the right. The bottom half of the figure describes the resulting flow of telemetry back to the Science Operations Centers (SOC) starting on the left with the payload, flowing to the MOC via the DSN and moving to the payload SOC on the right.

Mission Operations provides allowed instrument operation periods in the Orbit Activity File. Orbit Planning is discussed in detail in section 7. Spacecraft operations sends a few commands for the instrument when requested (i.e. power on and off) but the majority of instrument commanding is controlled by the instrument teams. Mission Operations coordinates the use of uplink availability by Spacecraft and Instrument teams. Instrument commands are inserted into

Instrument Supplemented Command Files (ISCF). Instrument sent ISCFs are verified by the instrument teams and not the MOC.

The SOCs instrument data processing operations are decoupled from spacecraft operations.

3.1 Spacecraft Telemetry

Spacecraft telemetry is distributed from the MOC to each of the instrument suite SOCs by three different methods as stated in the MOC-SOC ICD (7434-9078).

3.1.1 Raw Telemetry Frame Archive

The MOC maintains a raw telemetry frame archive that contains all real-time and Solid State Recorder (SSR) telemetry received via the Deep Space Network (DSN) from the spacecraft. The archive comprises the unprocessed telemetry files as delivered from the DSN. It is intended to be a safeguard against loss of data due to incorrect processing and is not intended to be accessed on a regular basis.

3.1.2 Time-Indexed Archive of Telemetry Packets

The MOC maintains a disk-based online time-indexed archive containing both spacecraft and instrument raw telemetry packets; associated applications are capable of serving this telemetry to clients via TCP/IP streams. This is the only archive that stores real-time telemetry. Clients include SOCs, assessment tools, and MOC applications to generate products for the SOCs. The archive supports a TCP/IP data stream interface, as described in the MOC-SOC ICD.

3.1.3 MOC Data Server Telemetry Data Files

All raw data files received from the SSR will be available in files on the MOC data server for the duration of the operational phase of the mission, plus one additional year as described in the MOC-SOC ICD. The instrument telemetry stored to the SSR during science operations will be available from this repository via SFTP.

The MOC Span Report available in the MOC data server, will list the consecutive ranges of telemetry packet sequence counts per Application Process Identifier (APID) by Spacecraft Time. The MOC Gap Report also available in the MOC data server, will list the consecutive ranges of telemetry packet sequence counts that are missing from telemetry storage.

The MOC will also make spacecraft attitude and ancillary data available to the instrument suite SOCs as described in the MOC Data Product Document (7434-9139).

The SOCs will pull the raw SSR files and ancillary data from the MOC and generate their quick-look and higher-level data products within the timeframe specified in the Mission Requirements Document (MRD 7434-9047).

3.1.4 Real-Time Level-Zero (L0) Telemetry Files

L0 telemetry is minimally processed, “cleaned and merged” spacecraft real-time telemetry. Any duplicates that occur because the data was received at multiple ground stations are removed.

Duplicate packets are defined as packets with the same spacecraft time (partition and integer MET), APID, and packet sequence count. The MOC maintains a disk-based online file archive of L0 telemetry files. This archive is a component of the MOC data server.

3.2 FIELDS

3.2.1 SOC Data Flow

The FIELDS Science Operation Center (SOC) consists of two main components:

- The FIELDS SOC Command, Telemetry, and GSE (CTG) component, which is primarily responsible for providing the FIELDS command interface to the MOC, monitoring basic instrument state-of-health (SOH) through the production of quick-look and trended SOH products, as well as supporting the FIELDS GSE interface during instrument and spacecraft integration and test (I&T).
- The FIELDS Science Data Center (SDC) component, which is responsible for fetching FIELDS L0 data from the SPP MOC, and the production and dissemination of all higher-level (L1 through L4) FIELDS data products and ancillary data. L1 to L4 data products are computed by this collection of modules, archived, and served to any external sites as required.

The overall SOC Data Flow is illustrated in Figure 3.2.1a, which shows the configuration of the FIELDS SOC systems for on orbit operations. Additional detail on FIELDS commanding is specified in Section 3.2.1.1. The production of SDC data products is illustrated in Figure 3.2.1b, which shows how low level FIELDS data products are created directly from FIELDS telemetry, and how additional spacecraft and instrument data are used as inputs for higher-level FIELDS data products.

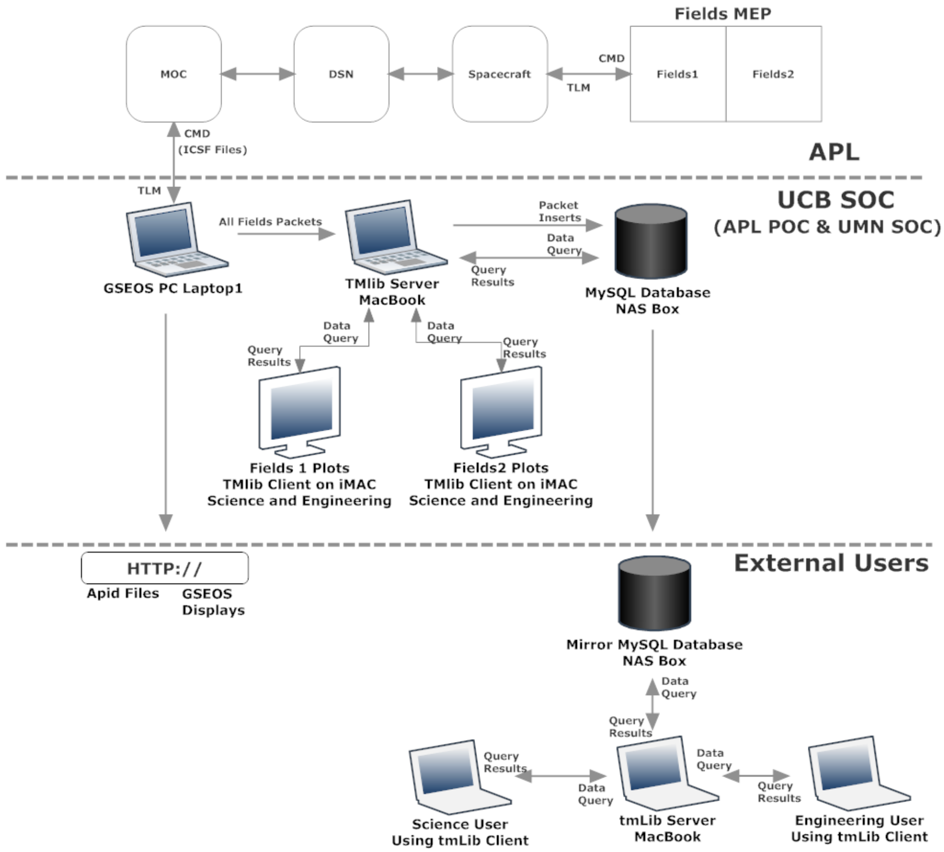

Figure 3.2.1a Overall Flow Chart for FIELDS SOC Data

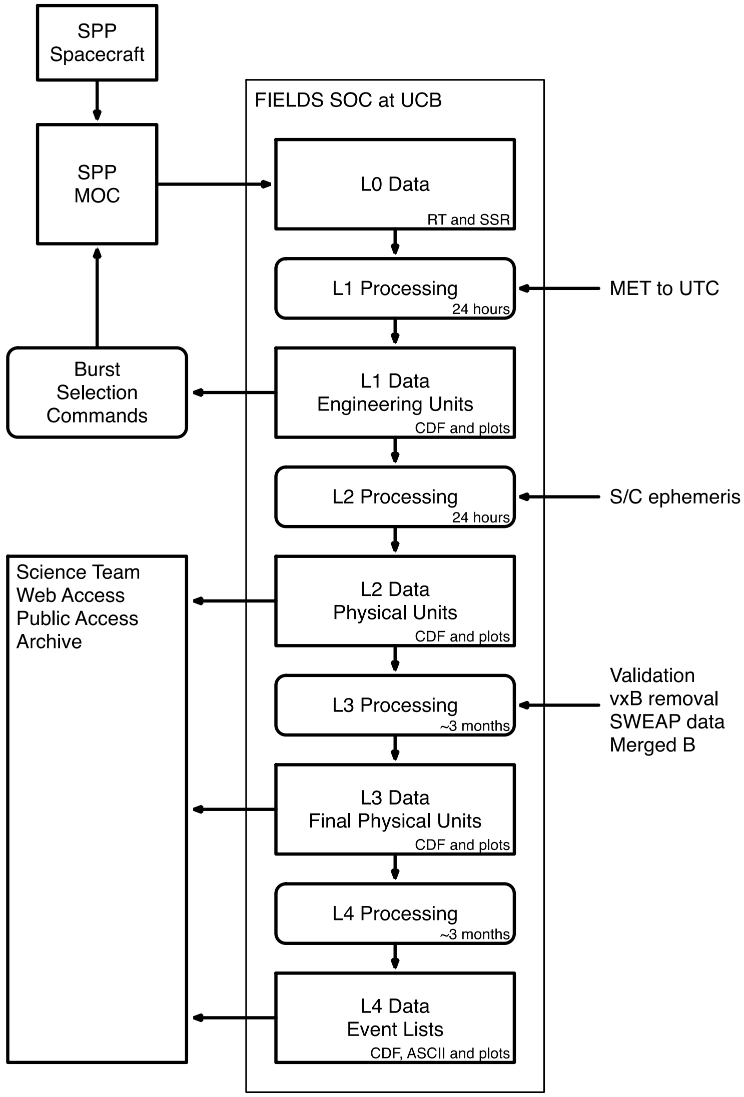

Figure 3.2.1 b Overall Flow Chart of FIELDS SDC

3.2.2 Commanding and Health and Safety Operations

FIELDS commanding and health and safety operations are implemented via SOC-CTG. The FIELDS SOC-CTG is based on the GSEOS system running on PC laptops at UC Berkeley Space Sciences Laboratory (UCB SSL). Commanding and health and safety operations are also implemented at the University of Minnesota (UMN).

The FIELDS-CTG will provide the communications layer to and from the MOC as required by the MOC-SOC ICD.

The primary CTG-specific functionality will be to "package up" valid FIELDS command sequences according to the required MOC format, to send those sequences to the MOC, as well as to receive near-real-time telemetry streams during instrument and spacecraft I&T and on-orbit commissioning operations.   This communications layer will be implemented in GSEOS. The

FIELDS SOC will generate and validate commands and command sequences prior to transmission to the MOC. Evolving from a command and telemetry database used throughout FIELDS I&T, the on-orbit command generation software will automatically generate only valid commands (that is, commands with valid parameters and validated constraints). Following testing for command integrity, the commanding software will verify correct UTC to MET time conversion on all relevant commands, and perform checks to ensure safe transmission of the commands to the MOC.

CTG monitoring of telemetry and commanding of the FIELDS instrument during commissioning, will be provided through in-person staffing of the FIELDS SOC in an IT-secure location, either in the PSP MOC, or at the FIELDS SOC at UCB. The FIELDS engineering, SOC and science teams will be able to view the CTG GSEOS session in real time, and, if required, issue commands or request specific diagnostic output. During normal operations, the CTG remote sessions (e.g. a VNC session) will run in read-only mode, with the GSEOS session displaying the standard state-of-health and data diagnostic displays as requested by the SOC and science teams. FIELDS commanding will take place in the IT-secure FIELDS SOC location.

Prior to being sent to the PSP spacecraft, commands will be tested and verified to ensure compatibility with the on-orbit instrument. The FIELDS SOC-CTG equipment will include an interface to the FIELDS instrument test-bed consisting of the FIELDS engineering model. As planned, the EM will be electrically and functionally identical to the FIELDS flight instrument, allowing for a high-fidelity replication of FIELDS instrument response to commanding. FIELDS instrument commands, as well as any necessary flight software updates, will be tested and verified on the test-bed prior to being sent to the MOC for upload to the spacecraft.

Scripted and on-demand production of state-of-health plots and data products are handled by a separate process based on instrument housekeeping in the L0 data stream. These data and plots will be available minutes from receipt of data and will be provided through the FIELDS SDC website.

3.2.3 Telemetry Processing Pipeline

FIELDS telemetry will be processed, archived and disseminated via SOC-SDC. The FIELDS SDC is responsible for all data processing and dissemination of Level-1 data products and above. The FIELDS SDC will be implemented on PC-based systems as part of the existing UCB SSL computing infrastructure (firewall security, automated backup, ancillary data access).

All data levels available to the public (Level-2 and above) will be provided in the ISTP-compliant CDF format. The files will be fully compatible with the Space Physics Environment Data Analysis Software (SPEDAS) suite of data analysis routines. Data will be made available through the FIELDS-SDC website either in the form of digital data (CDFs) or data plots.

Several ancillary data products are required for the complete and accurate reduction and production of higher-level FIELDS data products (L2+). These are the precision ephemeris and attitude data from the PSP observatory itself, as well as particle data from the SWEAP instrument. The ephemeris and attitude data are part of the standard MOC data products, and are archived locally at the FIELDS-SDC after acquisition by the FIELDS-CTG. These data will be used to produce FIELDS waveform data products in physically relevant coordinate systems, as well as in inertial or co-rotating reference frames (i.e. removal of the spacecraft frame –VxB E-field).

The FIELDS data products range from calibrated waveform data in spacecraft coordinate system, on-board and ground-processed spectral, cross-spectral, and interferometric estimates, through higher-level data products. Here, it is important to distinguish between efforts covered by the FIELDS-SOC and those covered by the FIELDS science team and their collaborators. As one proceeds from L2 (calibrated waveforms and spectral products) to L3+ data products (increasingly accurate DC E-field estimates), the burden of effort transfers from the SDC processing to actual analysis and research by the Science team, and while these higher-level data products will be made available publicly, it will be as part of the natural research efforts of the FIELDS science team and their collaborators.

Technical support for the end user (outside of the FIELDS team) will mainly be through the data file format itself – the CDF format is self-descriptive, and will include information on any caveats on the data and on the processing history of the data files. Each data file will contain a disclaimer that the end user is encouraged to contact a member of the FIELDS instrument team to ensure proper use and interpretation of the FIELDS data prior to publication.

3.3 IS⊙IS

3.3.1 SOC Data Flow

Science data are produced by the IS⊙IS Science Operations Center (IS⊙IS-SOC) at UNH with inputs from each the EPI-Lo and EPI-Hi team leads. The IS⊙IS-SOC is comprised of a Command, Telemetry and Ground Group, the Science Data Group, the pipeline and other analysis software, the Command and Telemetry Archive and the Distributed Science Archive. The SOC web site serves calibrated data to the IS⊙IS and PSP teams and the public. The SOC will operate with relatively low latency, ensuring that the team has rapid access to data.

An overview of the SOC data flow is given in Figure 3.3.1a. One key component of the IS⊙IS-SOC data flow is the commanding procedure, which is described in section 3.3.2. The other key component is the telemetry pipeline. Raw data and telemetry (SSR files and realtime level 0 files) received at the IS⊙IS-SOC from the Mission Operations Center (MOC) via Secure File Transfer Protocol (SFTP) are ingested and the Level-0 data are unpacked into files by date and ApID. The Level-1 data are subsequently processed to produce higher-order data products as described in section 3.3.3.

Summary and housekeeping data represent small samples of the complete data set and are telemetered before all other science data. The summary data provide snapshots of the larger science dataset, allowing the SOC and science team to prioritize the science data intervals, and to preview data taken while the spacecraft was near perihelion. After completion of in-orbit commissioning and cross-calibration, the SOC delivers data products. The availability of all

ISOIS data are fully compliant with the science data policy defined in the NASA Heliophysics Science Data Management Policy.

The team retains data rights only for the time period necessary to ensure that the data are properly processed, calibrated, and verified. The SOC strives to make this period as short as possible after receipt of the original science telemetry and auxiliary orbit, attitude and spacecraft status information. To ensure timely data delivery, the ISOIS-SOC lead prepares and delivers the calibrated data to the NASA PSP Science Gateway and SPDF. The SOC also will prepare metadata in concert with SPDF. The centralized SOC maintains uniform data formats and deliver data products in CDF format as requested by NASA.

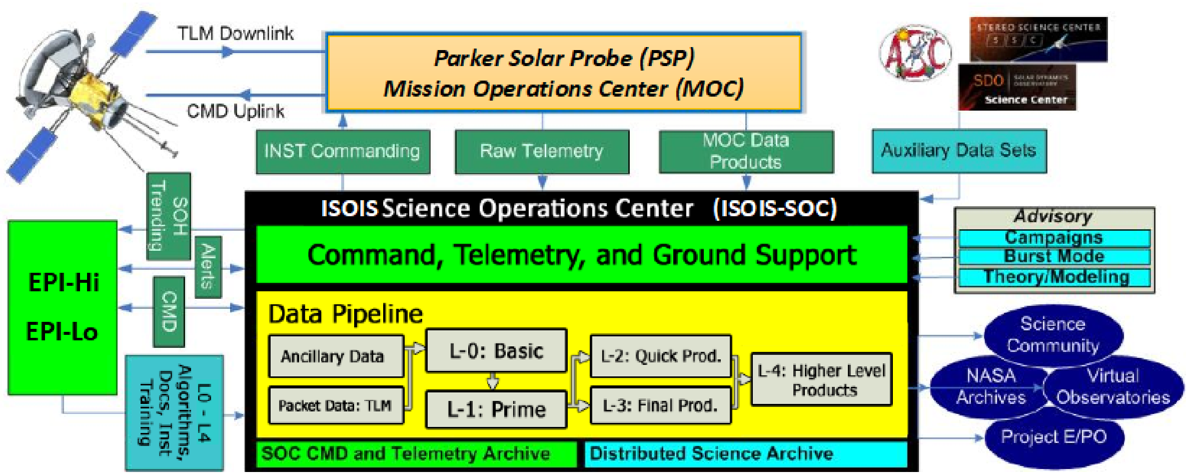

Figure 3.3.1a Overview of data flow through the ISOIS-SOC

3.3.2 Commanding and Health and Safety Operations

The Command, Telemetry and Ground (CTG) group is responsible for uploading instrument commands, validating command requests from the instrument teams, generating coordinated command sequences, receiving science and ancillary data from the MOC, monitoring the instruments' state-of-health, responding to alerts in coordination with the PSP instrument teams, producing time-information for instrument data and housekeeping, and supporting ground testing and routine operations from pre-flight to post-flight.

The ISOIS-SOC has a common framework that flows through Ground Support Equipment Operations Systems (GSEOS) through development of the engineering models, flight models, integration and test and to flight operations. We apply the concept of "test as you fly, and fly as you test". The common framework enables the ISOIS-SOC to develop as the team builds and learns to operate the instruments.

Instrument commanding and telemetry monitoring are facilitated via the GSEOS platform operating on shared virtual network computing (VNC) sessions hosted on the ISOIS-SOC server. Both the EPI-Hi and EPI-Lo instrument teams are provided with independent sessions with independently configured and maintained GSEOS instances. SFTP connections to the PSP MOC at APL provides for transfer to the MOC of command files and transfer from the MOC of instrument telemetry (see Figure 3.3.2a). A near-real-time connection between the SOC and MOC to GSEOS provides for near-real-time instrument commanding and instrument monitoring. Commands submitted via GSEOS are grouped and packaged into Instrument Supplemented Command Files (ISCF) and transferred to the appropriate command queue at the MOC, where they await uplink to the spacecraft.

In the event that the SFTP connection between the MOC at APL and the SOC is lost, there is a backup laptop at APL with software that is updated on the same cadence as updates at the SOC.

Furthermore, IS⊙IS is dedicated to thorough testing and verification of command loads and interfaces. The EPI-Hi and EPI-Lo teams have provided instrument simulators, which run a version of the instrument flight software suitable for operation without attached sensors. The SOC uses these simulators to verify command loads prior to sending them to the MOC. In addition, the IS⊙IS-SOC also applies a series of constraint checking modules to command loads.

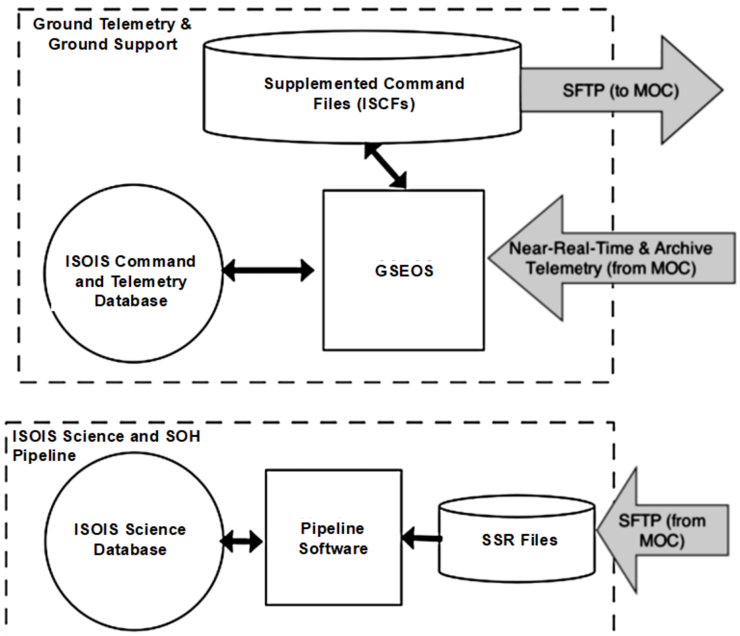

Figure 3.3.2a Commanding and telemetry handshakes between IS⊙IS-SOC and APL-MOC

3.3.3 Telemetry Processing Pipeline

The Science Data Group (SDG) serves as the repository for processing software and supports the PSP team throughout the project by:

- Processing Level-0, 1, 2, 3 and 4 data products
- Developing data analysis tools in coordination with the instrument teams and PSP communities
- Generating summary and quick-look plots

- Consolidating PSP data products with auxiliary data sets
- Serving data and analysis software to PSP communities
- Developing a database of models and derived quantities

Three types of software support the creation and analysis of science data for IS⊙IS: software for integrating and testing of the data products and pipeline, IS⊙IS-SOC components for processing telemetry into calibrated data products, and visualization tools for displaying and manipulating science data products. Supporting material, including documentation and software when relevant, are provided to enable the long-term correct and independent usability of the different data levels.

The IS⊙IS-SOC pipeline is designed to be quickly and autonomously rebuilt if need be. This functionality presents the added benefit of autonomously building the entire telemetry pipeline in a test environment that is completely independent of the active pipeline. New data products, updated versions of existing data products, and their end-to-end integration within the current pipeline can be tested in a stable environment without the risk of affecting active operations.

A clone of the MOC data server holding the SSR Files is maintained on the SOC server using the rsync utility. When new CCSDS packets are arrive in the SOC clone of the data server, they are placed into a SQL telemetry database and appended to an ingest/extract queue. A Python utility is used to unpack the CCSDS packets and extract the Level-0 data products. These data products are then placed into the pipeline processing queue, and a copy is also stored in the appropriate instrument's Level-0 data products repository. The copy placed into the pipeline processing queue is then used to identify the relevant Level-1 data products, or children, that are to be produced using the Level-0 file in question. Each of the children are added to a production queue.

Once all Level-1 children have been identified and placed in the production queue, the processing drivers invoke the relevant software for processing telemetry into calibrated data products. This data product-specific software is developed in coordination with the EPI-Lo and EPI-Hi teams. If it is found that not all Level-0 parent files required to build a specific Level-1 data product are present in the Level-0 repository, all instances of that Level-1 child are removed from the production queue and a single instance is appended to the end of the production queue. In this manner, a Level-1 child will cycle through the queue indefinitely until all of the necessary parents are downlinked from the spacecraft. When a Level-1 data product is created via the production queue, a copy is placed into the pipeline processing queue and another is placed in the appropriate instrument's Level-1 data products repository. This process is repeated indefinitely to produce all higher order data products.

The library of analysis software is maintained in a version control system downloadable to other sites maintained within the team. The analysis software is written in platform-independent languages such as Python and Java for the pipeline software. Additional languages such as MatLab, IDL, and the Perl Data Language reproduce pipeline analysis tools and provide additional analysis capabilities.

3.4 SWEAP

The SWEAP Science Operations Center (SOC) at the Smithsonian Astrophysical Observatory (SAO) in Cambridge, MA, and supported by facilities at the University of California, Berkeley (UCB), consists of two components. The first component is the Instrument Commanding and Operations (ICO). This component is responsible for creating the command plans for the instruments, monitoring instrument health and safety, as well as retrieving telemetry from the MOC. The second component is the Science Data Center (SDC), which will process, distribute, and archive the SWEAP data.

3.4.1 SOC Data Flow

The SWEAP SOC Data flow is described in Figure 3.4.1a. Telemetry data from the PSP MOC is rsynced to the SWEAP commanding computer at SAO. The data pipeline then processes and creates files for storage in the archive. Data processed to Level-2 and above are distributed to the public via the SWEAP website and the SPDF.

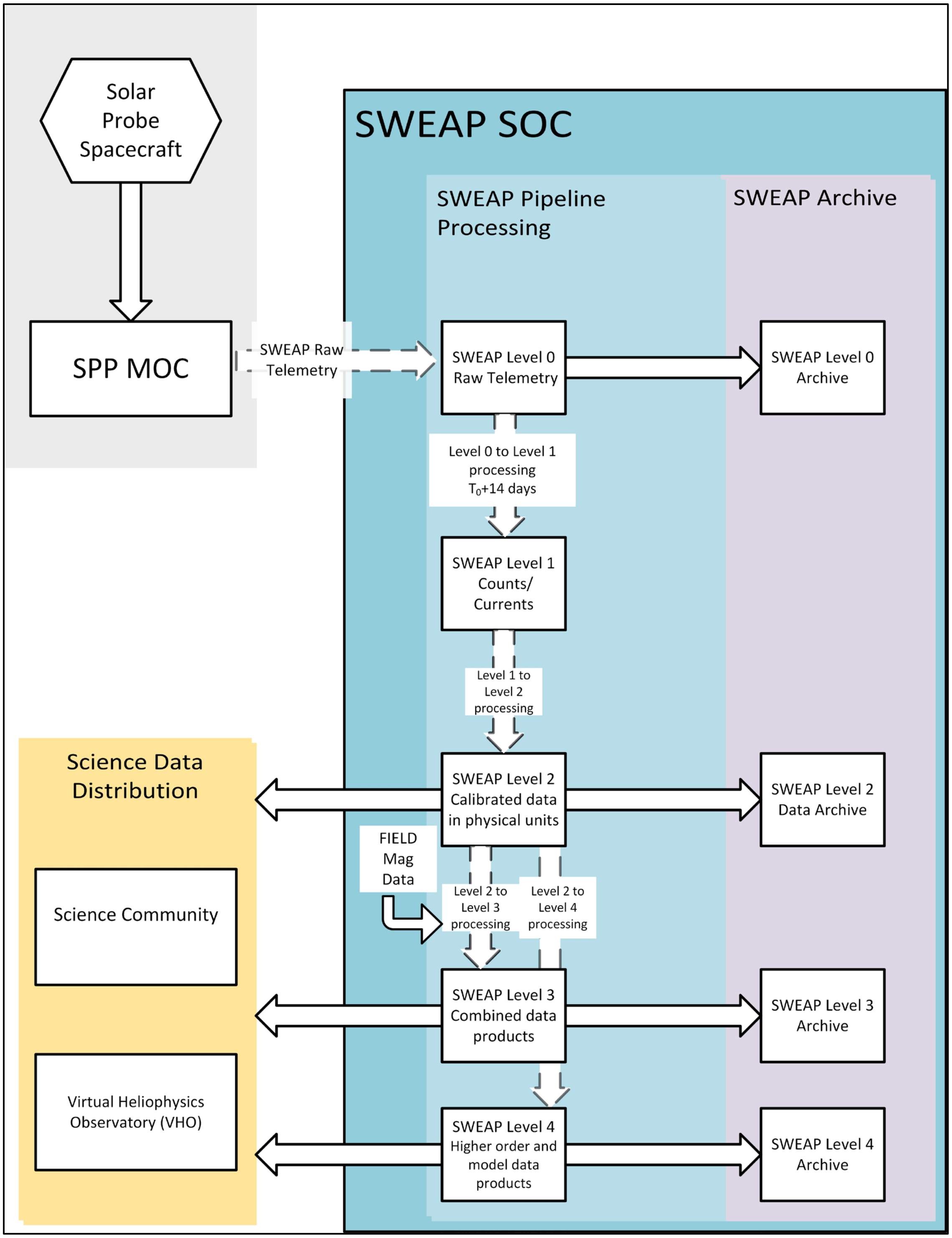

Figure 3.4.1a SWEAP data flow through the SOC

3.4.2 Commanding and Health and Safety Operations

The ICO supports PSP Mission Operations as required and provides key forecast and planning information for the Science Data Center. The ICO will utilize GSEOS for real-time commanding and for generation of ISCFs for SWEAP commanding. UCB serves as the primary commanding station, while SAO has backup capabilities for commanding of the SWEAP suite.

The ICO will plan for an encounter and command the SWEAP instrument suite. A meeting is held prior to each encounter to design an observing plan. This general plan is used by the individual instrument planners to details the specific commands in the command telemetry worksheet. The ATS generator performs validation and verification by checking the command validity and conflicts in timing of commands, after which an Absolute Time Sequence (ATS) file is created. This ATS contains the full list of instrument commands to be executed during the encounter, and the time at which those commands will be executed. Further validation and verification is performed when the completed ATS is run through SWEAP RackSat (located at UCB) to confirm that the commands execute correctly, the expected data volume is created, and the instruments behave as expected. After the ATS is validated, the ICO submits the Instrument Supplemented Command File (ISCF) file to the MOC by a predetermined time (typically just prior, or during a pre-approved communications pass in which SWEAP has been approved for commanding). The ICSF file(s) is (are) stored in a MOC queue. The MOC does not generate commands for the SWEAP suite, but acts as a pass-through for the ICO-generated commands. When contact is made with the spacecraft, the MOC queue is opened and the command file is transmitted to the spacecraft. The SWEAP Electronics Module (SWEM) then uses this file and its internal onboard command database in order to enact all of the commanded actions.

The ICO monitors the trends of instrument performance (voltages, currents, temperatures, etc.) and compares those observed values with predictions to enable anomalous trends to be noticed before they become a serious problem.

The ICO will be responsible for retrieving raw telemetry from the MOC. This telemetry will be transferred to a local SWEAP SOC computer in order to enter the Science Data Center Pipeline.

3.4.3 Telemetry Processing Pipeline

The SDC will manage the Science Data Center Pipeline necessary to support pipeline processing of SWEAP data, provide high-quality and easily usable data to the scientific community, provide a secure long-term archive for the data products, and submit data products to NASA for permanent archive. The flow of data through the SDC is illustrated in Figure 3.2.3a. The ICO will pull over the telemetry from the PSP MOC. The SDC will then process the data from Level-0 to Level-4. Specifically, SAO is responsible for the production of Level-2/3 data for the SPC instrument and UCB is responsible for the production of Level-2/3 data for the SPAN instruments. Level 4 data products are still being designed, and will likely be a shared responsibility of both SAO and UCB.

The SWEAP data Level-2 and above require ephemeris data from the spacecraft. Level-3 and above additionally require ancillary data from the FIELDS team as well as ephemeris data from the spacecraft. The FIELDS data will be obtained through transfer between the teams that is arranged by the SWEAP and FIELDS SDC. The spacecraft ephemeris data will be pulled from the MOC archive by the SWEAP ICO.

The primary access point for the SWEAP data will be the SWEAP SOC website:
http://sweap.cfa.harvard.edu/pub/data/sci/sweap/
The data will also be available through SPDF / CDAWEB,
https://cdaweb.gsfc.nasa.gov/istp_public/
https://cdaweb.gsfc.nasa.gov/pub/data/psp/sweap/
and through the PSP science gateway:
https://sppgway.jhuapl.edu/

The SWEAP data user's guide is provided on the same web archives as the data user's guide:
http://sweap.cfa.harvard.edu/sweap_data_user_guide.pdf and
https://cdaweb.gsfc.nasa.gov/pub/data/psp/sweap/sweap_data_user_guide.pdf)
user's guide contains the PSP data use policy and encourages the user to contact the SWEAP PI and instrument team in order to analyze the data most effectively.

3.5 WISPR

3.5.1 SOC Data Flow

The WISPR ground system data flow is illustrated in Figure 3.5.1a. The data are downlinked from the spacecraft to the PSP MOC. The ground system software (GSEOS) running at the WISPR SOC at US Naval Research Laboratory (NRL) retrieves the data from the MOC and processes the data into housekeeping and image files. The pipeline processing generates database updates for the WISPR MYSQL database.

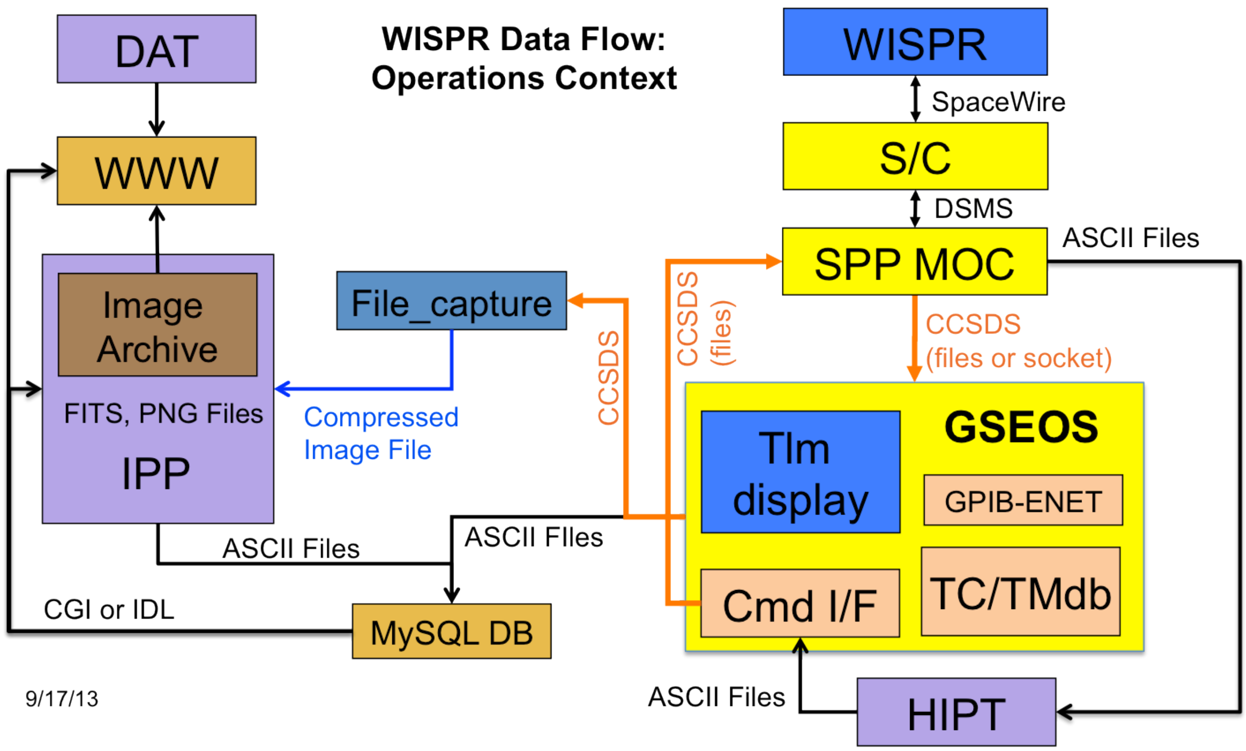

Figure 3.5.1.a WISPR ground system data flow.

3.5.2 Commanding and Health and Safety Operations

3.5.2.1 Telemetry Monitoring

Spacecraft telemetry received at the MOC during contacts is monitored for out-of-limit conditions. WISPR operations staff are notified via e-mail or phone call when WISPR-related telemetry is out of limits.

3.5.2.2 Observation Planning

While not risking damage, commands controlling observations do need to accommodate power, telemetry, and IDPU constraints. This is accomplished with the WISPR Heliospheric Imager Planning Tool (WHIPT) to model observations. At the SOC, WISPR personnel generate an observation plan for each orbit with the WHIPT, including calibration sequences. The WHIPT translates the plan into instructions that are uploaded to the WISPR IDPU and generates human-readable reports and graphics to communicate what each schedule entails. The WHIPT also accepts input from and provides input to the PSP observatory level planning system as part of the iterative process to optimize observations for all the instruments.

3.5.2.3 Command Verification

The WISPR SOC at the NRL utilizes the GSEOS software suite provided through APL to send command files to the PSP MOC via SFTP for uplink to the spacecraft. A small subset of commands may be designated by the WISPR System Engineer as “critical” because if generated at the wrong time, they could result in damage to the instrument. If so designated, when these commands are issued the GSEOS requires the operator to verify in real time that the command is to be sent.

Prior to every command load, there is a review process that includes a checklist of items to verify, such as appropriate sequence of events and whether the observations and timeline have been tested.

3.5.2.4 Command Backup

The nominal procedure is for commands to be sent from the WISPR payload operations workstation at NRL. For the event that commanding cannot be accomplished from NRL, a backup workstation is maintained at APL.

3.5.3 Telemetry Processing Pipeline

The SOC receives real-time telemetry from the MOC via socket connection, or playback telemetry in Level-0 files transferred by rsynch over ssh. Housekeeping telemetry is used to populate a MySQL relational database vi GSEOS. Science telemetry is captured from Level-0 SSR files into compressed-image-files which are processed in the Image Processing Pipeline (IPP) to Level-1 FITS files. These files, along with browse data and other data products, are available publicly via the WISPR website (https://wispr.nrl.navy.mil).

The primary mode of telemetry handling is playback of Level-0 SSR telemetry files from the MOC. A Telemetry and Command System (TCS) workstation converts the Consultative Committee for Space Data Systems (CCSDS) Space Packet Protocol packets in the Level-0 files to compressed image files and database input scripts.

The payload operations workstation at the WISPR SOC displays the WISPR and PSP spacecraft telemetry received in real time via socket connection to the PSP MOC during spacecraft contact. This workstation has the ability to output the same type of products as with playback.

3.5.3.1 Instrument Telemetry Database

A relational database of WISPR housekeeping and image header data has been created and is accessible via both WWW and Interactive Data Language (IDL) interfaces.

3.5.3.2 Image Processing Pipeline

The WISPR IPP software takes as input the compressed image files from the TCS workstation. It uses appropriate routines or executables to decompress the image files into integer arrays which are output as Level-1 (uncalibrated scientific data units) image files in the Flexible Image Transport System (FITS) format. Values for the FITS header are obtained from the WISPR HK database, PSP attitude history files, PSP ephemerides, and the compressed image file header. SPICE routines in the Solarsoft library are utilized for obtaining spacecraft attitude and orbit information. The WISPR image header is defined in the WISPR Data Product User's Guide. The IPP also generates database input scripts with data from the compressed image file header data.

After generation of the Level-1 FITS files, various higher-level products are generated. The latest calibration is applied to the Level-1 FITS files and saved to as a Level-2 (calibrated) image. A calibrated background image is generated from each Level-2 image and saved as a Level-2b (background) image. Additional products generated in the IPP are included as selected Level-3 products including background-removed images and subsidiary products as, e.g., browse images and movies. Scans for synoptic maps (e.g., Carrington maps and height-time maps or J-maps) are under development and will be released as Level-4 data when those are ready for automated production. Most of the code in the IPP will be available in the Solarsoft library.

4 DATA PRODUCTS

4.1 Definitions of Data

NASA categorizes Data Products based on a system of Levels starting with Level zero. A level zero data product is usually defined as representing raw, but cleaned spacecraft telemetry; subsequent data levels represent successive levels of data processing involving calibration and the application of science algorithms. The PSP mission has defined five data levels that are described in the table below (table 4.1a). The suggested latency in releasing data to the public is an indication of the complexity in producing these products some of which would require careful analysis and verification.

Data Level	Brief Description	Latency Goal
L0	Reconstructed, unprocessed instrument data at full resolution; any and all communications artifacts, e.g., synchronization frames, communications headers, duplicate data removed.	14 Days
L1	Instrument count rates at full resolution with supporting ancillary data (such as spacecraft ephemeris) needed for further processing. L1 data can be further split into L1A and L1B; L1B data would be calibrated L1 data needed to support L2 processing	14 Days
L2	Calibrated data presented in the appropriate scientific units and transformed into relevant heliophysical coordinate systems.	30 Days
L3	Data that has been irreversibly transformed to the point that lower level data can not be reconstructed. Data may be calibrated, re-sampled, and/or averaged.	90 Days
L4	Higher-level data products that require significant effort in processing and involve the use of models and additional external data sets. These products may be produced for a subset of the complete dataset only	1 Year

Table 4.1.a PSP mission defined data product levels

Notes:

- Data levels do not have a direct correspondence to "Quick Look" and "Final Data", terms used in the Mission Requirements Document. "Quick Look" and "Final Data" can be derived from any data level beyond level zero – the definitions of "Quick Look" and "Final" are independent of this table (definitions are provided below).

- The table above provides suggested data latencies that are not required, but rather are independent of the required data latencies for Quick Look and Final Data products as references in the Mission Requirements Document. Both required and suggested latencies will likely be surpassed once automated data processing is in place.

Data levels are defined as a "best match" to existing NASA missions. The detailed descriptions of the data products (sorted by level) for the individual instrument teams are given in the following sections. A summary of these products is given at a mission level in Table 4.1.b

Data Level	FIELDS	SWEAP	ISOIS	WISPR
L0	Raw CCSDS data packets, real-time Level 0 files and SSR binary files.	Raw CCSDS data packets, real-time Level 0 files and SSR binary files.	Raw CCSDS data packets, real-time Level 0 files and SSR binary files. Response rates and events packets.	Raw CCSDS data packets, real-time Level 0 files and SSR binary files.
L1	Uncompressed and decommutated L0 + Time-tagged waveform and spectral data in telemetry and engineering units [V, dBs, nT] in spacecraft coordinate system. Daily CDF files. Quick Look and daily/orbital summary plots.	Decommutated packets (SPANs) Instrument Currents (SPC)	Time series of uncalibrated instrument science and engineering rates at highest resolution. Unpacked particle event data.	FITS files with uncompressed images. Image values are in raw counts (DN).
L2	L1 + Time-tagged waveform and spectral data in fully calibrated physical units [V, mV/m, nT, $(V/m)^2/Hz$, nT^2/Hz] in spacecraft and heliophysical coordinate systems. Daily CDF files. Quick Look and daily/orbital summary plots.	Calibrated Particle flux (Calibrated and in physical coordinates and units) Solar Wind moments and energy spectra (Calculated onboard, calibrated, in physical coordinates and units)	Time series of calibrated particle intensities at highest time, energy, and look-direction resolution, in physical units.	FITS files with calibrations applied. Image values are in units of brightness. FITS files of the background image computed for each calibrated image
L3	L2 + VxB removal for DC E-field measurement, offsets and corrections with data quality flags.	Solar wind bulk parameters, energy spectra, and electron pitch angle distribution (Calibrated and	Time series of calibrated particle intensities, averaged into appropriate sets of larger time,	Data products are the result of combining two or more images (movies, Carrington maps, etc). May or

	Plasma density. Spacecraft potential. Merged B. Merged density and temperature (FIELDS-SWEAP) CDFs, Science data plots	calculated on the ground)	energy and look-direction bins. Time-series plots of the above items.	may not be calibrated in physical units.
L4	Event (shocks, current sheets, radio bursts, stream interaction regions) time tags and parameters. Ad hoc.	Derived power spectra, source location, and event lists	Particle spectra and fluences for specific events and/or periods. Particle anisotropy parameters/plots.	Derived quantities (electron densities, CME masses etc).

Table 4.1.b Mission Level Data Products

4.1.1 Definitions of Planning, Quick-look and Final data products

Planning and Browse Data

Planning products are data products that are quickly produced to aid in the operations planning process in-between instrument teams. Browse products are quickly produced to aid in operations planning, data selection or instrument health and safety monitoring. Planning and browse data are considered preliminary and cannot be cited, published or presented without the permission of the corresponding Principal Investigator.

Quick Look Data

The intention of quick look data is to provide a scientifically useful data product within a few days of acquiring data. These data are considered preliminary and cannot be cited, published or presented without the permission of the corresponding Principal Investigator.

Quick look data can be deleted or replaced once final calibrated data is available.

Final Data

Final data is defined as data delivered to the public that is of use to the science community, but is subject to revision and recalibration as described in section 4.2.

In the tables below, T_0 represents the time after the last data from the orbit has been received at the instrument SOC.

4.1.2 Instrument Data Product Descriptions

The following tables represent the Science Data Products, their contents, format, latency, and frequency of production. The volume is the estimated data volume of data products based on the current allocation of data. When the allocation changes, those estimates will change. The latency in this table represents the initial best efforts to produce scientifically useful data to be released to the PSP team. Reprocessing after additional information or calibration is obtained will be needed before the data becomes final.

4.1.2.1 FIELDS

Data Level	Product Title	Contents	Volume	Format	Latency	Frequency
L0	Raw telemetry	Raw de-commutated telemetry data retrieved from MOC.	4 GB/orbit	Binary	T_0	As downlink schedule allows
L1	Waveform and spectral data.	L0 + Time-tagged waveform and spectral data in engineering units [V, dBs, nT] in S/C coordinate system.	16 GB/orbit	CDF files Quick Look & Summary plots.	T_0+ 1 day	As new data is available. Reprocesse d as needed.
L2	Calibrated waveform and spectral data.	L1 + Time-tagged waveform and spectral data in physical units [V, mV/m, nT, $(V/m)^2$/Hz, nT^2/Hz] in heliophysical coordinate systems.	24 GB/orbit	ISTP-compliant CDFs Quick Look & Summary plots.	T_0+ 2 days	As new data is available. Reprocesse d as needed.
L3	Calibrated waveform data with VxB removal, other more highly processed products.	L2 + VxB removal for DC E-field measurement, offsets and corrections with data quality flags. Plasma density. Spacecraft potential. Merged B. Merged density and temperature (FIELDS-)	32 GB/orbit	ISTP-compliant CDFs, Science data plots	T_0+ 1 orbit	As new data is available. Reprocesse d as needed.
L4	Event data	Event (shocks, current sheets, radio bursts, stream interaction regions) time tags and parameters. Ad hoc.	Ad hoc	ASCII, Science data plots	T_0+ 1 orbit	As developed.

Table 4.1.2.1a FIELDS Data Products

4.1.2.2 ISΘIS

Data Level	Product Title	Contents	Volume	Format	Latency	Frequency
L1	Science Rates	Uncalibrated instrument science rates at highest resolution	<510 Mbytes/day	ASCII, CDF	T_0+ 14 days	Upon receipt of data from MOC, checked every 12 hours.
L1	Engineering Data	Uncalibrated instrument engineering rates at highest resolution, HK data, Cmd-responses.	<45 Mbytes/day	ASCII, CDF	T_0+ 14 days	Upon receipt of data from MOC, checked every 12 hours.
L1	Event Data	Raw event data, unpacked into data structures, but otherwise unprocessed.	<300 Mbytes/day	ASCII, CDF	T_0+ 14 days	Upon receipt of data from MOC, checked every 12 hours.
L2	High-Resolution Particle Intensities	Calibrated electron, proton, and heavy-ion particle intensities at highest time, energy, and look-direction resolution, in physical units. See L4 Instrument Requirements Doc for details.	<510 Mbytes/day	ASCII, CDF	T_0+ 90 days	Per orbit, unless required for planning. Reprocessed as needed.
L3	Averaged Particle Intensities	Calibrated electron, proton, and heavy-ion particle intensities averaged into appropriate sets of larger time, energy and look-direction bins, in physical units. These products are derived from the *High-Resolution* Particle Intensities.	<360 Mbytes/day	ASCII, CDF	T_0+ 90 days	Per orbit, unless required for planning. Reprocessed as needed.
L4	Derived Data Products	Particle spectra and fluences for specific events and/or periods. Particle anisotropy parameters/plots.	As needed	ASCII, CDF	As needed for specific studies.	As needed for specific studies.

Table 4.1.2.2.a ISΘIS Data Products

4.1.2.3 SWEAP

Data Level	Product Title	Contents	Volume	Format	Latency	Frequency
L0	Raw Telemetry files	Raw CCSDS packets for SPC and SPANs and auxiliary information such as spacecraft ephemeris	~7 GByte per Data Collection Period (DCP)	Binary	T0=3 days after receipt from SPP MOC	As data is downlinked
L1	SPC instrument currents SPAN instrument count rates, onboard moments, and mass histograms	Nominal calibrations applied. Not all in physical units	<1 GByte/ DCP	PNG	T0+14 days	As Level-0 data is received; reprocessed as needed
L1	SPC instrument currents	Instrument responses not in physical units	<2 GByte/ DCP	CDF	T0+14 days	As Level-0 data is received; reprocessed as needed
L2	Reduced SPC particle distribution functions and solar wind flow angles Calibrated SPAN 3-D electron, proton and alpha distributions (and heavy ion distributions if possible) Not corrected for spacecraft effects SPAN onboard solar wind moments and energy spectra	Data in physical units to be used for scientific analysis	12 GBytes (SPC) 180 GBytes (SPE) 250 GBytes (SPI)	CDF	T0+30 days	As soon as data is available; reprocessed as needed
L3	Solar wind moments from	Ground calculated		CDF		

	SPC reduced distributions	parameters that include data from FIELDS. Data for scientific analysis	2 GByte (SPC)		T0+90 days	Reprocessed as needed
	SPAN solar wind moments, energy spectra, ion distributions, and electron pitch angle distributions (corrected for spacecraft induced effects)		20 GByte (SPE) 55 GBytes (SPI)			
	Joint SPC-SPAN solar wind ion parameters					
L4	Shock List	Derived parameters from calibrated data	TBD	ASCII Text and CDF	T0+1 year	A least once per orbit; reprocessed as need
	Event List					
	Power Spectra					

Table 4.1.2.3a SWEAP Final Data Products

4.1.2.4 WISPR

Data Level	Product Title	Contents	Volume (GB/orbit)	Format	Latency	Frequency
L1	Level-1 quick-look *	uncalibrated image data	~1	FITS	T_0+ 7 days	as received; track-dependent
L1	Level-1 final	uncalibrated image data	~15	FITS	T_0+ 7 days	as received; track-dependent
L2	Level-2 quick-look *	calibrated image data	~2	FITS	T_0+ 30 days	per orbit
L2	Level-2 final	calibrated L1 images	~30	FITS	T_0+ 90 days	per orbit
L2b	Level-2 final	calibrated backgrounds	~30	FITS	T_0+ 90 days	per orbit
L3	Level-3 final	calibrated images with background removed	~30	FITS	T_0+ 90 days	per orbit
L3	Browse movies & movies	browse images & movies (from L3-final)	~1.5	PNG, MPG	T_0+ 90 days	per orbit
L4	J-maps	time-elongation plots (from L2 or L3)	~1.5	PNG	T_0+ 1 year	annually
L4	Synchronic or Carrington maps	heliospheric brightness at selected elongation angles	~0.15	FITS, PNG	T_0+ 1 year	annually
L4	CME masses		2	FITS	T_0+ 1 year	annually

Table 4.1.2.4.a WISPR Data Products

* The WISPR L2 quick-look data is an interim product providing an initial look at the encounter observations before complete processing and calibration. The L2 “Final” data set replaces the quick-look L2. When the calibration factor is updated (infrequently), the ops team regenerates the Level-2, Level-2b, and Level-3 data. A best and final Level-2, Level-2b, and Level-3 dataset will be provided after end of mission.

4.2 Revision Control

Data products are subject to both version and revision control. The data product version number indicates how many times the content or format for the product has changed. Modifications to processing software, changes to calibration or other input files, and product format changes are all examples that would cause the version number to increment. The PSP Instrument Team will track data product versions by incorporating that information into both the product filenames and in the appropriate metadata.

The data product revision number indicates how many times the product has been regenerated with the same processing software as well as the same input and calibration data files. Data entry errors, transmission problems or other types of failures may cause a product to be re-released and thus have the data product revision number incremented. The PSP Instrument Team will track data product revisions by incorporating that information into the appropriate metadata.

4.3 File Formats and Naming Conventions

The individual SOCs have coordinated their file formats and naming conventions with Space Physics Data Facility (SPDF) for FIELDS, ISOIS and SWEAP and Solar Data Analysis Center (SDAC) for WISPR.

4.3.1 FIELDS

All FIELDS data products are provided in ISTP-compliant CDF files. The data file format is:

psp_fld_<LEVEL>_<DATATYPE>_<YYYYMMDD[hh]>_<VERSION>.cdf

<LEVEL> identifies the data level (example: “l2” for Level 2 data)
<DATATYPE> identifies the type of data (example: “rfs_lfr” for RFS LFR data)
<YYYYMMDD(hh)> identifies the time interval covered in the data file. Most FIELDS data files are 24 hour daily files, e.g. “20181106”. Some large volume data types, such as Level 2 full time resolution magnetometer data, are split into four daily files to reduce individual file size, e.g. “2018110600”, “2018110606”, “2018110612”, and “2018110618”.

4.3.2 IS⊙IS

All IS⊙IS data are provided in NASA Common Data Format (CDF) files and are fully self-describing via embedded ISTP/SPDF compatible metadata. Variables that are most likely to be of interest in science have a VARIABLE_PURPOSE attribute including “PRIMARY_VAR”. Each file contains one UTC day, based on the timestamp of the midpoint of data collection.

The file naming convention is described by SPDF as “source_descriptor_datatype_yyyyMMdd” with an appended version, i.e. filenames are of the form “psp_{descriptor}_{datatype}_{date}_v{release}.cdf” where:

- *source* is always “psp” for Parker Solar Probe, and is thus written as such here.
- *descriptor* is the instrument included in the file. Files containing only EPI-Lo data are “isois-epilo”; EPI-Hi data, “isois-epihi”. Files containing data combined across the instruments of the IS□IS suite have descriptor “isois”.
- *datatype* further describes the data in the file. It consists of multiple subparts separated by ASCII hypen (-).
    - The first part is always the letter “l” followed by a single number, for the level of the data, e.g. “l2” for level 2 data
    - Further parts vary depending on the instrument and the data product. EPI-Lo files usually contain the mode, “ic”, “ie”, “pc”, or “pe”. (The EPI-Lo instrument cycles between modes several times a second, so the data collection in each mode appears to be simultaneous..) EPI-Hi files usually contain the telescope and the cadence, e.g. “let1-rates3600” for the hourly rates from the LET1 telescope

- *date* is the UTC date of the data contained within the file in format YYYYMMDD.
- *release* is the release number of the data. This is zero-padded to a two digit number. The IS□IS team prepares a release of the data after the downlink of each data collection period (DCP). Additional releases may be prepared as necessary to provide significant updates to the scientific community in between scheduled releases. Each release contains data for the entire mission; the latest release should always be used for publication.

Thus the file "psp_isois-epilo_l2-ic_20191216_v03.cdf" contains level 2 EPI-Lo ion composition mode data from 2019-12-16, release 3.

An exhaustive description of each data product, including summary information and a list of every variable, is available from the IS⊙IS SOC website, at https://spp-isois.sr.unh.edu/data_public/ISOIS_Data_Glossary.pdf

4.3.3 SWEAP

File formats and naming conventions, are available in the SWEAP data user's guide: http://sweap.cfa.harvard.edu/sweap_data_user_guide.pdf

4.3.4 WISPR

All WISPR image data are in the FITS file format and are named according to the following convention:

psp_LX_wispr_YYYYMMDDTHHMMSS_VX_WXYZ.fits

where LX is the file level (L1, L2, L2b, L3); YYYYMMDD is the year, month and day; T separates the date and time; HHMMSS is the time in hours, minutes and seconds; VX is the file release version (V1, V2, etc., see below); and WXYZ are parameters that describe the type of image. W is 1 or 2 to indicate whether the image is WISPR-I or WISPR-O, respectively; XY are digits that identify the camera readout microcode used to control the camera; and Z is an indication of the camera microcode region [0...6] and is 1 or 2 for synoptic images.

The data product version number (VX in the FITS file name) indicates how many times the product has been generated. Modifications to processing software, changes to calibration or other input files, and header (metadata) changes are all examples that would cause the version number to increase. Data entry errors, transmission problems or other types of failures may also cause a product to be re-released and thus have the data product version number incremented. The data product version is tracked by the VERSION keyword in the FITS header and also indicated in the filename. Version zero (V0) in the filename indicates a quicklook data product; its VERSION number in the header may increment but the quicklook filename will not change.

4.4 Documentation

Links for the instrument documentation will be made available through the PSP Science Gateway at URL https://sppgway.jhuapl.edu/ under the Data Tab

4.4.1 FIELDS

The FIELDS-SDC will provide an online, publicly accessible repository for the following documents:

1. Instrument description (and links to published instrument papers).
2. Relevant scientific publications.
3. SPF_MEP_105_SWEAP_ICD FIELDS-SWEAP Interface Control Document.
4. Calibration procedures and methods.
5. Validation through cross-calibration between the Observatory ephemeris, FIELDS and other PSP instruments.
6. Description of each data product (this will also be available in the CDF file attributes).
7. Description of metadata products

Links to all of the above documents will be made available at http://fields.ssl.berkeley.edu/.

4.4.2 IS⊙IS

EPI-Hi and Lo teams will provide the following documentation products:

1. A detailed Instrument description document
2. A data Calibration and Validation methodology document, and online calibration files
3. Dataset description
4. Metadata products (SPASE definitions and CDF file attributes, etc.) for the appropriate VO.

The above documentation will be made publicly available on the SOC website to be linked from the mission page and PSP Science Gateway https://sppgway.jhuapl.edu/. The IS⊙IS-SOC provides a manual detailing operation of software and elements of the ground systems. All documentation is available to IS⊙IS instrument team members via the IS⊙IS-SOC server.

4.4.3 SWEAP

The SWEAP SOC will provide an online, publicly accessible repository for the following documents on the SWEAP website (http://sweap.cfa.harvard.edu)

1. Published instrument papers
2. Algorithms and Theoretical Basis Document for processing of each sensor's data.
3. SWEAP Data User's Guide (http://sweap.cfa.harvard.edu/sweap_data_user_guide.pdf)
4. Data release notes for each instrument:
   - 4.1 http://sweap.cfa.harvard.edu/spc_data_release_notes.pdf
   - 4.2 http://sweap.cfa.harvard.edu/spe_data_release_notes.pdf
   - 4.3 http://sweap.cfa.harvard.edu/spi_data_release_notes.pdf
5. Calibration procedures and methods.
6. Metadata products (as contained in self-documented CDF files)

4.4.4 WISPR

Documentation necessary for data analysis and interpretation will be made available on the WISPR website (https://wispr.nrl.navy.mil). These will include

1. Instrument description
2. Calibration and Validation methodology
3. Validation through cross-calibration with other instruments or other assets (if applicable)
4. Dataset description including FITS header definition
5. Metadata products
6. List of special events such as CMEs, comets, etc.

4.5 Processing and Analysis Tools

4.5.1 PSP Science Gateway

The Parker Solar Probe mission architecture has no centralized Science Operation Center (SOC). Instead, individual instrument suites maintain their own SOCs and serve science data from those SOCs. This approach has the great advantage of leaving the responsibility of processing and delivering the data in the hands of the instrument teams who have the necessary scientific expertise. On the other hand, there is the disadvantage is that the mission lacks of a centralized data center which the scientific community can access all the mission desired data in a single place. To address this shortcoming, the Parker Solar Probe mission developed the concept of a "Science Gateway", which is a web site focused on the science investigation and provides a single point of entry for each instrument SOC.

The site, as will be illustrated below, provides access to:

- plot and retrieve scientific data, including Space Weather data
- planning tools, e.g. Multi-Mission Orbit Plotter
- ancillary data like the PSP SPICE kernel files
- Parker Solar Probe related bibliography

See the Appendix: SPICE kernel files for more information on the kernels available on the Science Gateway.

The URL for the Science Gateway is https://sppgway.jhuapl.edu/. The features available on the Science Gateway are described in greater detail in the Appendix.

4.5.2 FIELDS

All higher-level data products will be produced at the FIELDS-SDC and distributed from there. Codes to process data from one level to another will be maintained and run at the FIELDS-SDC. The end user should have no need to run these codes, but will have access to the codes for L1+ processing through the SPEDAS-based analysis tools.

Data will be in the common CDF format for which many readers and utilities exist in a variety of languages (IDL, Matlab, Fortran, C, Python) and on a variety of platforms. There is no intention to distribute dedicated readers in these languages.

For the FIELDS science team, the IDL-based set of FIELDS analysis routines from the Space Physics Environment Data Analysis System (SPEDAS) will be provided. The SPEDAS software suite will be able to access the FIELDS SDC directly from the FIELDS SOC server.

SPEDAS provides access to data products from many missions, and can be used to display and browse data on a common time scale and to make publication-quality plots.

4.5.3 IS⊙IS

The IS⊙IS SOC will provide all data in self-describing CDF files with ISTP-compliant metadata, compatible with a wide range of browse and analysis software. File development is coordinated closely with CDAWeb personnel, who have extensive experience with file formats and software from a variety of missions.

The IS⊙IS team provides quicklook summary plots via the autoplot tool which can also be used for interactive browsing of the data. The team also provides a custom IDL tool to support more involved interactive data visualization and analysis; this is available to the public via the IS⊙IS SOC website. These tools are supported entirely by the standard embedded metadata within the fully-calibrated CDF files which also drive the CDAWeb interface.

4.5.4 SWEAP

The SWEAP SDC will process the raw telemetry received from the PSP MOC to produce and distribute higher-level data products. The codes associated with processing the data through the SWEAP data pipeline will be maintained and run at the SWEAP SDC. The data will be distributed in the Common Data Format (CDF) which can be read into and manipulated in several scientific programming languages such as IDL, Matlab, Fortran, C, and Python.

4.5.5 WISPR

The radiometric calibration of the data was originally performed using the pre-flight laboratory calibration data. Calibration updates are made during the mission using observations of an ensemble of stable stars, as was done for SOHO/LASCO and STEREO/SECCHI. The calibration team monitors the detector telemetry and the images and provides periodic updates to the science calibration routines. The pipeline procedure converts the Level-1 FITS image files into Level-2 calibrated images after correcting for vignetting and stray light and uses the results from the stellar photometry to convert the images into mean solar brightness units (MSB). The correct geometric distortion model, determined from the star field, is also added into the header in the standard world coordinate system (WCS) formalization. After the calibration is performed a background image (L2b) can be generated for that image and hence the corresponding background-removed image (L3) created. The calibration procedures and all calibration data necessary for these corrections will be included as part of the Solarsoft distribution which is publicly available at http://sohowww.nascom.nasa.gov.

Software tools for common analysis tasks that are in use for LASCO, SECCHI, and SoloHI are being extended to incorporate WISPR data. These include image visualization, generation of movies, feature tracking, structure measurement, and combining datasets from multiple remote-sensing and in-situ instruments and spacecraft. Forward fitting of three-dimensional models to heliospheric features such as streamers and CMEs are also provided in Solarsoft. NRL will work with the Community Coordinated Modeling Center (CCMC) at NASA Goddard Space Flight Center to produce appropriate heliospheric model calculations for comparison with the WISPR data for each Carrington rotation, as well as for selected events of interest. The results of these model calculations will be made publicly available on the WWW.

5 DATA ARCHIVE

In the Heliophysics Data Environment, data are efficiently served through distributed active and (long-term) resident archives. The PSP Science Gateway will not hold data. For the PSP mission this is each instrument team's responsibility as documented in the following sections.

After a mission ends, data from each Investigation will typically remain accessible through each Investigations's Resident Archive that maintains easy access to data and expertise for its use. The maintenance and serving of the mission archive can be performed by a "Resident Archive" associated with mission data experts. The Mission Archive Plan will show the path to creating the mission's Resident Archive(s) and the subsequent Final Archive(s).

The FIELDS, IS⊙IS and SWEAP instrument teams are providing their data to the SPDF and the WISPR team is providing their data to the SDAC.

5.1 SSR Files

All raw data files received from the spacecraft SSR will be available in files on the MOC data server via sftp for the life of the mission plus one year. The on-line period and details are documented in the 7434-9078 PSP MOC to SOC ICD.

5.2 FIELDS

5.2.1 Backup Strategy

Level-0 data received by the FIELDS-SOC will be backed up automatically at UCB SSL. These data files are compatible with the existing near-real-time and stored data processing tool available at UCB SSL to the FIELDS team. Since these data files will also be archived by the MOC, this will provide a redundant archive.

The FIELDS team at UMN serves as a backup to the SOC at UCB. All Level-0 data is downloaded to UCB as well as UMN, and stored using the same database system. UMN also produces some FIELDS data products, originating from the FIELDS2/TDS instrument on FIELDS. All FIELDS data products are synced between UMN and UCB, with copies of all data files regularly synced (on a daily basis). The IDL code used to produce data products is also synced between the two locations.

Level-1-4 data will similarly be backed up at UCB servers, using the existing backup structure maintained by SSL IT personnel. Data on the SSL server is backed up offsite at the Iron Mountain facility in Sacramento.

5.2.2 Reprocessing Strategy

As data are reprocessed, this will be documented through the usual CDF file version numbers mechanism as well as the production of a FIELDS orbital data availability map. Addition of new data (e.g. from arrival of a new spacecraft SSR file at the MOC) will not result in a version number increment–the number will be incremented upon a significant change in the flight or ground processing software.

5.2.3 Long Term Archive

The FIELDS team will implement the SPP Mission Archive Plan once it becomes available. It is envisaged that UCB SSL will be able to support NASA's "resident archive" model for post-mission access to the FIELDS data. The long term FIELDS data archive will also be held at the Space Physics Data Facility (SPDF). Data that the FIELDS SOC serves on its website can automatically be ingested into the SPDF. The backup and archive capabilities of SPDF will ensure long term backup and access to the data.

5.3 IS⊙IS

5.3.1 Backup Strategy

The SOC will store Level-0 through Level-4 data products in a science archive, which will be made available to the science community online. Intermediate products used solely for the production of these data will not be archived. Other items that are also backed up include:

- The git repository containing cfengine rules and related files
- IS⊙IS telemetry database
- IS⊙IS data processing database
- Website files
- Version-controlled source code repositories for locally developed code
- Encrypted user passwords
- Logs and cfengine run output files
- User home directories and data files
- Final data products output from the processing chain
- MOC data server files that are not on the IS⊙IS instrument (project kernels, etc.)

With the downloadable data and pipeline analysis tools, sites for science analysis can be mirrored at essentially any site maintained by the members of the science team. The pipeline software and distributed science archive are housed and backed up at UNH. Multiple backups of both the distributed science archive and the pipeline software will be maintained at the SOC.

Materials not backed up include:

- Intermediate data products (scratch files, temporary files, etc.)
- Operating system files (the latest versions are available from vendor)
- System configuration files (cfengine rules handle creating the appropriate configurations)

5.3.2 Reprocessing Strategy

Reprocessing of data is executed automatically when newer versions of processing codes added to the processing repository. The distributed science archive will also maintain a version control system (such as subversion) for all science data products. The defined by a release and two-digit version number to track updates to the data product processing software in both the filename and metadata.

The file version information is a two-digit release number, e.g. v01: Release data. All release data with the same version number has been processed with the same set of codes; releases will roll forward as additional data are available and able to be processed with the old codes. If new or updated codes are required, the entire mission archive will be reprocessed and receive a new release number. Releases are a manual-decision, automatic-support process: the SOC team will choose to perform a release in coordination with the instrument teams and the release process is executed by script.

The internal data version is a three-field x.y.z number, e.g. 1.2.0. This version number represents the version history of that particular date and product and will only be available to the ISOIS and PSP teams. These are reprocessed automatically, with a new version number, as new data arrive.

5.3.3 Long-term Archive

The final archive, including internal documentation, code, and all levels of data, will be delivered to a deep archive at the National Space Science Data Center (NSSDC) or other archive of NASA's choosing within 12 months of end of mission.

5.4 SWEAP

5.4.1 Backup Strategy

SWEAP Level-0 data will be automatically backed up at SAO and at UCB in order to have geographically separate backup copies in addition to the original copy stored at APL.

SWEAP SPAN Level-1 data will not be archived. The Level-0 SPAN archive and the associated processing algorithm described in the algorithm document are sufficient to reproduce the Level-1 data if necessary. SWEAP SPC Level-1 data will be archived at SAO and UCB on a RAID or RAID like storage devices.

SWEAP Level-2- 4 data will be archived at SAO and UCB on a RAID or RAID like storage devices.

If the main SWEAP data archive at SAO is down for maintenance or due to hardware failure, the website serving the data will be redirected to the UCB archive until appropriate recovery steps have been taken. This insures the access to the data with little to no interruptions. The SWEAP team will also work with NASA's Space Physics Data Facility (SPDF) to serve all data products which adds another level of redundancy.

5.4.2 Reprocessing Strategy

In general, data will be reprocessed when significant new calibration or improvement to an algorithm is made. When any archived data is reprocessed, the file names will be incremented with appropriate version/revision number as well as noted in the data release notes on the SWEAP website.

5.4.3 Long Term Archive

The long-term data archived will be held at the SPDF. Data that the SWEAP SOC serves on its website are ingested into the SPDF. The backup and archive capabilities of SPDF will ensure long term backup and access to the data. The SWEAP team intends to support the PSP mission archive plan once it becomes available as long as it can be implemented within the constraints of the archival forms already available from the SWEAP team.

5.5 WISPR

5.5.1 Backup Strategy

A complete archive (data products, metadata, planning documents, analysis software, etc.) will be maintained at NRL at least during the full mission lifetime. There will be at least two off-site copies of the complete archive, updated at least daily. One copy is located at the NASA/GSFC SDAC facility and integrated into the Virtual Solar Observatory (VSO). A second copy is located at one of our European partner institutions, the Institut für Astrophysik in Göttingen, Germany (http://cgauss-psp.astro.physik.uni-goettingen.de/data.php). WISPR data will be migrated to new storage hardware as part of the NRL Solar and Heliospheric Physics Branch long-term data maintenance plan. There is no plan to have the full data set on a removable storage media such as DVD.

5.5.2 Reprocessing Strategy

Reprocessing is necessary when the calibration evolves. Stellar transits through the field of view are used to update the absolute photometry. After the end of the operating mission, the calibration will be updated and the image data will be reprocessed. The reprocessing history for a FITS data product is indicated in the FITS header.

5.5.3 Long-term Archive

The WISPR team will provide the final instrument calibration and a complete best and final Level-2 (and Level-2b) calibrated and Level-3 background-removed data set from the entire mission to the NASA/GSFC SDAC archive at the end of Phase E or the end of the extended mission.

6 DATA AVAILABILITY

NASA has an open data policy that high-quality, high-resolution data, as defined by the mission goals, will be made publicly available as soon as practical. The individual instrument teams are responsible for making their data products publicly available as described in the sections below and will work with the PSP Science Gateway, SDAC and SPDF to promote the distribution of their data.

6.1 Data Access Policy

6.1.1 FIELDS

6.1.1.1 Final Data

All data from Level-2 data products and above will be publicly available, together with any other ancillary data available at the time. These data will be served from the FIELDS-SDC website, http://fields.ssl.berkeley.edu, and can be accessed by ftp or http-clients.

Users who elect to use the TDAS-derived analysis package will further be able to download the data and access it remotely through that package.

6.1.1.2 Quicklook Data

Quick look data plots will be made from Level-1, Level-2, and Level-3 CDF files at daily and orbital cadences. Quick look plots using data from Level-2 and above will be made available for browsing at the FIELDS SDC website, http://fields.ssl.berkeley.edu.

6.1.2 IS⊙IS

6.1.2.1 Final Data

Level-2, through Level-4 data products will be publicly available to the NASA archives, the SPDF, NASA virtual observatories and the science community. The SOC acts as the active resident archive for the lifetime of the mission and beyond.

Level-0 and Level-1 data products will not be made publicly available but will be included in the final archive.

6.1.2.2 Quick Look Data

Quick look data for Level-1 and higher data products will be hosted on the SOC website as plots only. Since quick look data are not meant to be cited, no digital data will be available for public use.

6.1.3 SWEAP

6.1.3.1 Final Data

All SWEAP data Level-2 and above data products will be publicly available. This data will be served through the SWEAP Science Operations Center website https://www.cfa.harvard.edu/sweap/science_data.html.

All SWEAP data Level-2 and above will be incorporated into and available for download by the scientific community through the SPDF.

6.1.3.2 Quick Look Data

Quick look data (plots of SPC L2 data, and L2/L3 data that have not yet been validated) are available to SWEAP team members and representatives of each other PSP instrument team on a password-protected location on the SWEAP website.

6.1.4 WISPR

6.1.4.1 Final Data:

Final data of all levels, the calibration data and the house keeping data are completely open to the public. FITS and browse images, and movies for the science windows of each orbit are available at the WISPR web site. The science data can be accessed through the WISPR web site query tool. They are also available through VSO. Final Level-1, Level-2, Level-2b, and Level-3 data are released to the public 90 days after all of the data for an encounter or observing window is received at the SOC.

Note that the Level-2b and Level-3 data sets are currently only processed for observations taken from within 0.5 AU and only for the "sun-pointed, unrolled" attitude of the S/C. Observations taken under other S/C attitudes (e.g., rolled and/or off-pointed) and/or outside of 0.5 AU are not processed for Level-2b and Level-3 because the scarcity of data precludes a systematic and consistent processing. Final Level-1 and Level-2 data, which do not depend on this processing, are still released for these data sets.

6.1.4.2 Quick Look Data:

The Level-1 quick-look data consists of the individual image files received from the spacecraft as received at the SOC. The Level-2 quick look data from WISPR provides a preview of the observations after receiving all of the observations from an encounter or observing window. They are of limited scientific utility. Processing and analysis of a complete set of data for scientific purposes is necessary to generate calibrated data and backgrounds. Level-1 and Level-2 quick-look data are released to the public 90 days after all of the data for an encounter or observing window is received at the SOC..

6.2 Data Release Schedule

A grace period of 6 months after downlink of all data for an encounter for the first two orbits, has been specified in the quick look data delivery requirements in the Mission Requirements Document, to allow for calibration of the instruments and refinement of the automated data processing.

Quick-look data is specified in the Mission Requirements Document to be released within 6 months of downlink of all the data for the first two orbits after launch and within 60 days of downlink for each orbit thereafter.

Final data is specified in the Mission Requirements Document to be released no later than 6 months from downlink of all data from an encounter, and receipt of all ancillary and other data sources.

The data archive from the operational phase of the mission is specified in the Mission Requirements Document to be delivered to the instrument teams respective NASA-designated location for a deep data archive within 12 months of completion of the operational phase of the mission.

6.2.1 FIELDS

The following availability schedule applies once routine data processing is fully automated:

Level-1 data products (which will not be made publicly available) will be automatically produced upon receipt of raw telemetry but will generally be quickly superseded by the publicly available Level-2 data.

Level-2 data products will be made publicly available within 90 days of receipt of data.

Level-2 data products will be made publicly available within 90 days of receipt of data.

Level-4 data products contain lists of events, with time tags and parameters determined by analysis of the lower level products. These lists will be updated and made publicly available when the science team adds additional events to the lists.

Reprocessing of data will be automatically triggered by newer versions of the relevant input files for a given level of processing becoming available. Reprocessing will generally be run daily.

6.2.2 IS⊙IS

Science and housekeeping products are produced autonomously at the IS⊙IS-SOC. The SOC produces the Level-1 data and makes them available to the team via the internet. Browse quality, and automated data of selected products will also be available to the full PSP team as soon as they are available. The detailed Level-2, Level-3 and Level-4 data analyses are performed by the instrument teams, and algorithms for the generation of these data products are provided to the SOC so that processing at Level-2 and higher can be performed at the IS⊙IS-SOC.

Data verification and validation will be partly automatic but will also include evaluation by scientists. Verification and validation processes will be coordinated by the ISʘIS Science Data Group. The SOC will store the data at all levels in a science archive, which will be made available to the science team online. With downloadable data and pipeline software, analysis and visualization tools are made readily available to all members of the PSP science team.

Level- 0 data products will not be made publicly available.

Level-1 data products will not be made publicly available.

Level-2 data products will be made publicly available within 90 days of receipt of data.

Level-3 data products will be made publicly available within 90 days of receipt of data.

Level-4 data products will be made publicly available as needed for specific studies.

6.2.3 SWEAP

Due to the variable timing of downloads based on spacecraft contacts during a particular orbit, the processing of data will have a variable time scale based on receipt of the data from the PSP MOC. The process once the data is received from the PSP MOC will be automated.

Level-0 and 1 data products consisting of data not appropriate for scientific analysis will not be made publicly available.

Level-2 and Level-3 data products are made publicly available according to the schedule given to the SWEAP team by the APL project scientist. Typically, this means the L2 and L3 data are released 90 days after the end of a Data Collection Period (DCP). As processing becomes more automatic, we hope to regularly deliver data prior to the required schedule.

Level-4 data products will be made publicly available within 1 year of receipt of telemetry and ancillary data from the PSP MOC, and after those Level-4 data products have been defined (many are still TBD).

Data will be reprocessed when new calibration or other ancillary files are obtained. Updated files are released publicly upon completion of the reprocessing of all the previously released files.

6.2.4 WISPR

There are two versions of WISPR processed science data: 1) quick-look data produced immediately upon receipt of any image telemetry from the spacecraft (including a low-latency "planning" subset), and 2) final data incorporating any telemetry packets that may be missing or corrupted in the quick-look telemetry and that are later recovered. Quick-look Level-1 data may be used for mission operations planning purposes.

Quick-Look:
The Level-1 data products are automatically produced upon receipt of Level-0 packets. These data products are automatically produced by the pipeline processing and are available immediately to the PSP team as they are generated.
The Level-2 quick-look data products are generated as soon as the Level-1 quick look data are ready. They are made available to the PSP teams as soon as they are generated. Level-1 and Level-2 quick-look data are released to the public 90 days after all of the data for an encounter or observing window is received at the SOC.

Final Data:
Level-1 data products are automatically produced by the pipeline processing upon receipt of Level-0 packets. These data products are available immediately to the PSP team as they are generated.
The Level-2 final data products are then generated to include corrections needed. They are then made available immediately to the PSP team.

Level-2b and Level-3 data products are generated only after the Level-2 final products are ready for release. These, along with the final Level-1 and Level-2 data are released to the public 90 days after all of the data for an encounter or observing window is received at the SOC.

Level-4 data products, such as J-maps, Carrington maps, and CME masses are under development during the course of the mission. As they become ready for automation, they will be prepared for the relevant subsets of the observed data and released to the public. The goal for this release is one year after the data for an encounter or observing window is received at the SOC.

Final Level-1 and Level-2 data replace the quicklook data. They are differentiated from the quick-look Level-1 data product by the VERSION information in the header and filename. The Final Level-1 and resulting visualization data products are (re-)generated after each orbit; these will be suitable for archiving and distribution. Both quick-look and final data are processed in the same way and have the same file formats.

6.3 Data Catalogues

6.3.1 FIELDS

All FIELDS data will be described and cataloged via SPASE XML metadata into the PSP project-defined VO. The SPASE metadata will become searchable through the VO with the search results pointing to the data located within the UCB publicly accessible FIELDS-SDC web site. The metadata describing all publicly available FIELDS data products will also be available from the FIELDS SDC web site, .

6.3.2 IS⊙IS

Final IS⊙IS data products, as provided by the IS⊙IS-SOC in CDF according to ISTP standards, will be catalogued by the SPDF and made publicly available via CDAWeb. Users of CDAWeb will be able to select subsets of the data catalog and obtain plots, original CDF files or listed data in ASCII format. Final data products and quick look plots will also be publicly available via the IS⊙IS-SOC website.

6.3.3 SWEAP

See Section 3.4.3 for a description of SWEAP's data pipeline and distribution process. Data are maintained on the SWEAP website, as well as in the SPDF archive. The CDF files provided to the SPDF (and available on the SWEAP website) are completely self-documented, and are used by the SPDF to create the necessary SPASE metadata files used in their archive.

6.3.4 WISPR

The WISPR project uses the open source database program MYSQL, which is also currently being used to manage the housekeeping and image header information on both SECCHI and LASCO. A web-based tool within the WISPR web site (wispr.nrl.navy.mil) enables searches of the image header database with the ability to select FITS files for download using FTP to the user's computer. The table structures are similar to the existing tables, but updated to accommodate PSP specific characteristics. For example, the existing IDL tools include the ability to extract any parameter(s) of interest and to generate plots against time or to correlate one parameter against another.

It is our intention that the FITS header will mirror the SPASE catalog. To the extent that the required keywords are known, they will be incorporated into the image FITS headers.

7 ORBIT PLANNING PROCESS

7.1 Planning

It is beyond the scope of this document to describe the entire PSP Orbit Planning Process so the focus in this section will be on activities that directly involve the Project Science team, Science Planning Leads and the Payload teams.

7.1.1 Orbit Planning Overview

The PSP mission is divided into time periods that make mission and science operations tractable. An orbit is the period between consecutive aphelia along PSP's trajectory, while an encounter is the period of primary science observation when PSP is within a distance of 0.25 AU of the Sun. The period outside encounter is sometimes referred to as a "cruise" period, although significant spacecraft and science instrument operations frequently occur during this period.

The orbit is divided up into a number of contiguous intervals called orbit segments. The orbit segments are manageable orbit pieces for the generation of command sequences. These segments are variable in length and will be designed to cover specific spacecraft or instrument activities, like the pre-encounter period or the encounter. The pre-encounter period is the time when spacecraft and instrument encounter activity commanding is uplinked.

See the following figure for an example of orbit segments for orbit 1. In this figure, PSPs orbit is divided up into 5 orbit segments based on the activities to be performed over the orbit.

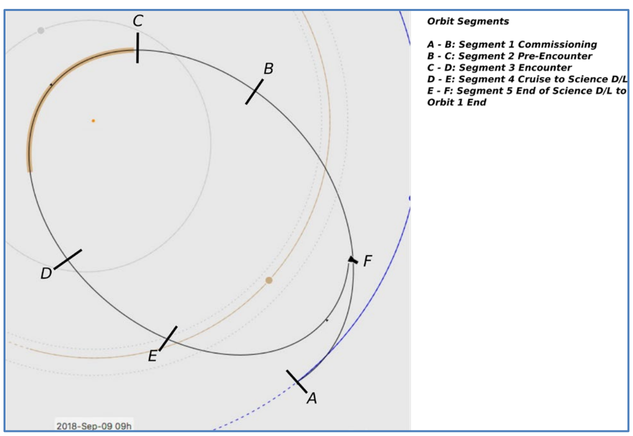

Figure 7.1.4 a: Example of orbit segments for orbit . The blue line is the orbit of the Earth. The gold line is the orbit of Venus. the gold dot is the Sun. The black line is the PSP spacecraft's first orbit. The gold band shows the encounter period.

The allocation and usage of spacecraft resources are organized according to data collection periods (DCPs) that are disconnected from the orbit and encounter time periods. A single DCP involves allocating data to each instrument suite, acquiring data up to these allocations, downlinking the acquired data, and freeing the spacecraft resources taken up by the downlinked data. The amount of data allocated to the science instruments is a function of the available space on the spacecraft solid state recorder (SSR) and the availability of Deep Space Network (DSN) communications sufficient to downlink the acquired science data.

There are a number of challenges for the Science Planning Team of the PSP mission. The geometry of the celestial bodies and the spacecraft during some of the mission orbits cause limited uplink and downlink opportunities. To add further complexity, three of the spacecraft payloads, FIELDS, SWEAP and WISPR, have the capability to write large volumes of data to their internal payload SSR while sending a smaller "survey" portion of the data to the spacecraft SSR for downlink. The instrument scientists would then view the survey data on the ground, determine the most interesting data from their payload SSR, and send commands to transfer that data from their payload SSR to the spacecraft SSR for downlink. The timing required for downlink and analysis of the survey data, identifying uplink opportunities for commanding data transfers, and downlink opportunities sufficient for the selected data within the DCP is critical.

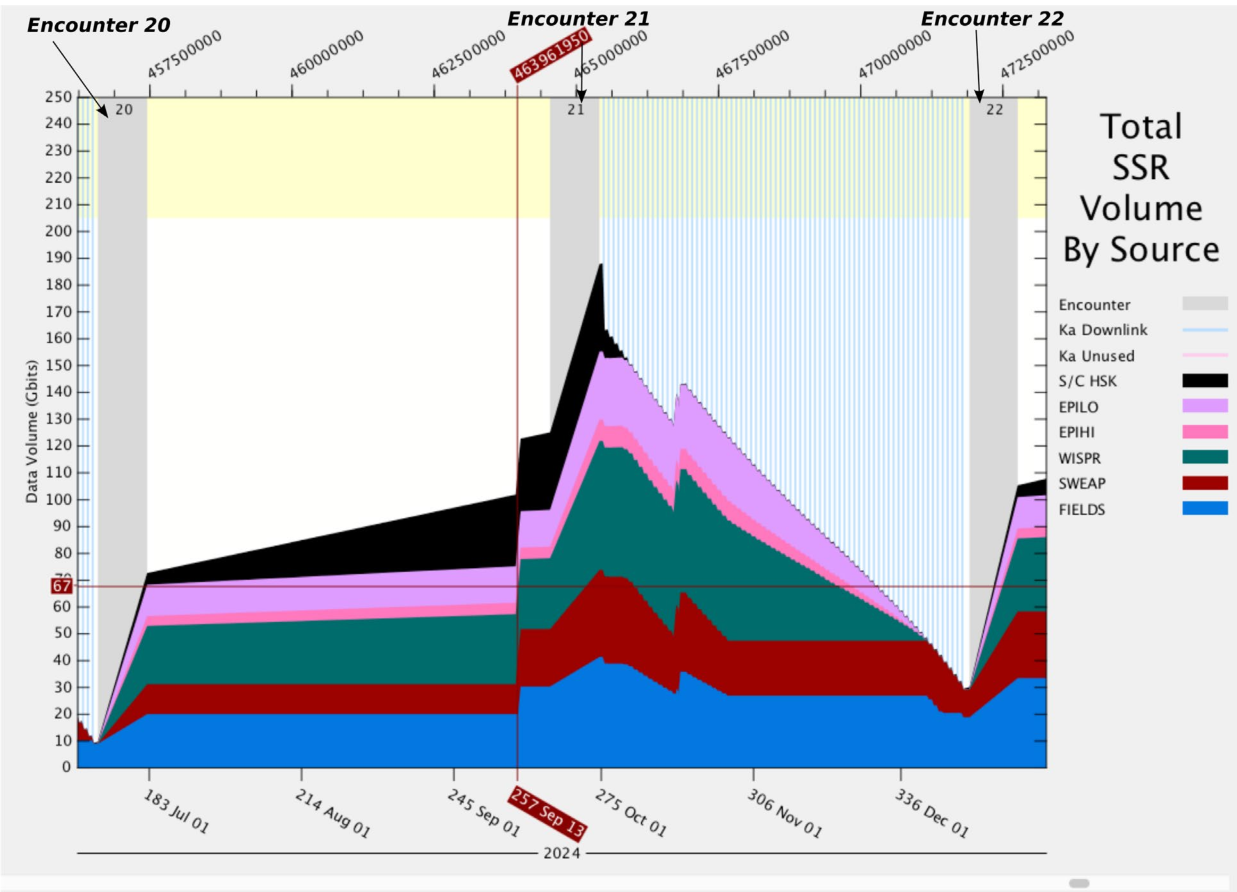

Figure 7.1 a: Example of orbit with no Ka-band downlink passes followed by an orbit with a great deal of downlink passes.

Due to these complicated scheduling and data allocation constraints, an automated way to input mission operations files and planned science data is needed. PSP Science Planning Analysis and Data Estimation Resource (SPADER) was created to address this planning need. SPADER is discussed in greater depth in the Appendix Planning Tools. To illustrate one aspect of this suite of tools, Figure 7.1.a shows a simulation illustrating the amount of data on the spacecraft SSR for periods including encounters 20 and 21.The plot displays total data in Gbits (10^9 bits) on the spacecraft SSR divided into individual instrument contributions and spacecraft housekeeping. The gray vertical bars are the encounter periods and vertical blue lines are the simulated periods of available downlink using the spacecraft high gain antenna (HGA) that operates using the high-rate Ka-band frequency. PSP contains multiple X-band frequency antennas with low downlink rates compared to the HGA; however, the sheer volume of science data collected makes the HGA antenna the only practical mechanism to downlink science data. The availability of Ka-band downlink passes is determined by the geometry of the celestial bodies and the PSP spacecraft, as well as the allowable attitude of PSP. There are periods during the mission when geometry and attitude constraints allow only X-band contact and not Ka-band contact (and vice versa). It is also common to have both X-band and Ka-band contact possible.

In the period between encounters 20 and 21, the lack of Ka-band downlink passes would cause the payloads to make a decision on what data to transfer from their internal SSR to the spacecraft SSR with no view into the data. The red cursor indicates that the SPADER simulation made the decision to transfer SWEAP and FIELDS selected data to the spacecraft SSR seven days before the next encounter since the survey data was not all downlinked before that period; however, this is a configurable decision within SPADER. In practice, under the conditions simulated, the instrument teams will likely not perform any transfer but would rather "stream" all their incoming science data directly to the spacecraft SSR.

In the period between encounters 21 and 22, there is a great deal of Ka-band downlink available. The figure illustrates how each orbit's data downlink availability is different and will require specialized planning to utilize it appropriately.

Detailed orbit activity planning is required in advance for each PSP orbit. Tight coordination between mission operations (MOPS) and the instrument teams will be required. The planning process described in this section will facilitate the coordination of spacecraft and payload activities by MOPS and the various instrument teams. The Science Planning Team will be required to coordinate with MOPS the availability of downlinks, data volume allocation, power on opportunities, command uplink opportunities, data transfer rate from instrument memory to the spacecraft SSR and the instrument data content in the spacecraft SSR.

	FIELDS	**SWEAP**	**EPI-LO**	**EPI-HI**	**WISPR**
P0 (Downlinked First)	Only urgent spacecraft and instrument housekeeping				
P1	Only spacecraft housekeeping				
P2	1%	1%	1%	1%	1%
P3	1%	1%	1%	1%	

P4	≤ 48%	≤ 50%	8%	8%	8%
P5					
P6			90%	90%	91%
P7 & P8 combined	≥ 50%	≥ 48%			
P9 (Downlinked Last)	Only spacecraft contingency housekeeping				

Figure 7.1 b: Science data priority table.

Figure 7.1.b is the science data priority scheme that was negotiated by the PSP Science Working Group (SWG). In the figure, S/C is spacecraft, HK is housekeeping, and P is priority. The left column shows priorities in downlink. P0 is priority 0 and will be downlinked first and P9 will be downlinked last. The teams are free to rearrange the percent of data written to different priorities provided that the rearrangement results in more data written to the higher priorities which are downlinked after the lower priorities.

Priority 1 contains the spacecraft nominal housekeeping and would only be used by an instrument during an instrument anomaly response, for example if an instrument's housekeeping values exceeded red alarm limits. The anomaly response would require real-time collaboration with MOPS.

Priority 2 contains instrument nominal housekeeping. Priority 3 contains instrument high value science. Instrument high value science has been identified by the instrument teams to be a very small set of science data to be downlinked first. An example of high value science would be telemetry that can be used to indicate the selected data to downlink later if the downlink availability does not allow the priority 4 data set to be downlinked quickly.

Priority 4 contains encounter survey data and Venus flyby data from the FIELDS and SWEAP suites, and a smaller amount of data from the other instruments. Survey data are used by the SWEAP and FIELDS team to make their selection of data on their internal instrument SSRs for downlink later.

Priority 6 data contains the bulk of downlinked ISΘIS EPI-HI, EPI-LO and WISPR data. Priority 7 and 8 data contain data from FIELDS and SWEAP. For FIELDS, the P4/P7 routing is controlled by the spacecraft, implemented via a change in the spacecraft packet filter table which is included in the spacecraft command load for each Encounter and Venus flyby.

Any adjustment of data volume and the data priority scheme required by the downlink availability of each orbit, will take place during the Data Collection Period Planning step described later in the section. Note that SSR files on the spacecraft SSR are downlinked first by file priority and secondly by file time.

One other priority (i.e. Priorities 5) is left open for use in case the mission needs to adapt the priority scheme at a later date.

Priority 9 is used for the spacecraft contingency housekeeping data, which comes down last. If the spacecraft remains in a nominal state, the priority 9 data will be periodically deleted. Instruments should not use priority 9 because it is periodically deleted and any data written there would still count against their data allowance.

7.1.2 Orbit Planning Meetings

There are two weekly PSP Orbit Planning Process meetings. The PSP Weekly Project Status meeting goes over current spacecraft and payload operations status and looks ahead a few weeks. The PSP Orbit Planning meeting is the major planning meeting and covers the plans for multiple orbits. Upcoming spacecraft and payload activities and changes to DSN passes are discussed.

Near the beginning of the orbit schedule, after the long range DSN schedule and initial OAF have been delivered, Orbit X Planning Kick-Off Meeting is held to go over the initial plans for the orbit. The meeting covers the orbit segment times, orbit special events, available downlink and uplink data volumes, planned spacecraft activities and planned DCPs.

7.1.3 Pre-Orbit Planning

These planning steps are performed before the orbit planning begins, because they require more lead time to evaluate and implement.

1. Any changes to the packet filter table or real-time downlink table should be reported to MOPS. The packet filter table determines the APIDs that go into the SSR files, and the desired file sizes. The SSR file sizes per APID is set up at the beginning and changes rarely. There is a possibility that these changes include on-board software changes.
2. Any new instrument activity types for inclusion in the Orbit Planning Tools would be communicated with MOPS. This would happen rarely; most activities have been set up before launch. Activities are high level spacecraft and instrument functions.
   Note: The addition of activity types would require some lead time for both Activity Planner and the PASF Merger software tools to implement.

7.1.4 Orbit Planning Products

This section describes the orbit planning products that the Project Science, Science Planning Lead and Payload teams would interact with.

DSN Contact Requirements – A spreadsheet that is used to estimate desired contact types and frequencies

DSN Schedule – The long range DSN schedule provides the expected downlink and uplink data rates and negotiated version provides the negotiated data rates.

Orbit Activity File (OAF) – The OAF is an ASCII file that contains a set of high-level time ordered spacecraft and payload activities. Some spacecraft activities define blackout periods when some or all instrument or spacecraft activities are excluded from operation. This is the method of communicating time periods when an instrument can be powered on outside of encounter. The OAF is created by the Activity Planner software which is described in the Appendix Planning Tools section.

The Activity Planner – Orbit Activity File Output & Activity File Ingest document governs the OAF ASCII content format. The OAF also contains the orbit segment start and stop times.

Payload Activity Sequence File (PASF) – The PASF is an ASCII file that contains a set of high-level time ordered activities for one or more instrument(s). The PASF is created using the SPADER PASF Merger which is described in the Appendix Planning Tools or the Payloads Planning software. A set of activities for each instrument have been negotiated between MOPS and the instrument planning teams to define activities that the spacecraft or other instruments need to know about. Some of the instrument activities require the spacecraft to send spacecraft commands on the instrument's behalf. Power on and off activities are an example of this. Another example of an instrument activity would be any activity requiring the uplink of a large command file which would need to be scheduled when adequate uplink bandwidth is available.

The instrument activities and their parameters are specified in the Instrument Activity Lists and are stored on the MOC Data Server.

The Activity Planner – Orbit Activity File Output & Activity File Ingest document governs the Payload Activity Sequence Files (PASF) ASCII content format. The PASF header content of the individual payload PASFs is further described in the 7434-9181 PSP Science Operations Planning ICD which also governs margins and other requirements for constructing a conflict free PASF.

SPICE Kernel Set

The PSP Science Gateway hosts the entire set of PSP SPICE files available to the public. If you are unfamiliar with SPICE kernels, please see the JPL Navigation and Ancillary Information Facility (NAIF) SPICE page, available at URL: https://naif.jpl.nasa.gov/naif/. The SPICE Kernels are described further in the Appendix.

7.1.5 Orbit Planning

This section will focus on the science related steps in the PSP Orbit Planning Process. Each planning process is described in detail in the following sections.

The PSP Orbit Planning Process is divided up into Pre-Orbit Planning, Orbit Planning, DCP Planning and Orbit Segment Planning. The 28 week orbit, DCP and orbit segment planning processes for PSP were designed to allow margin in the schedule.

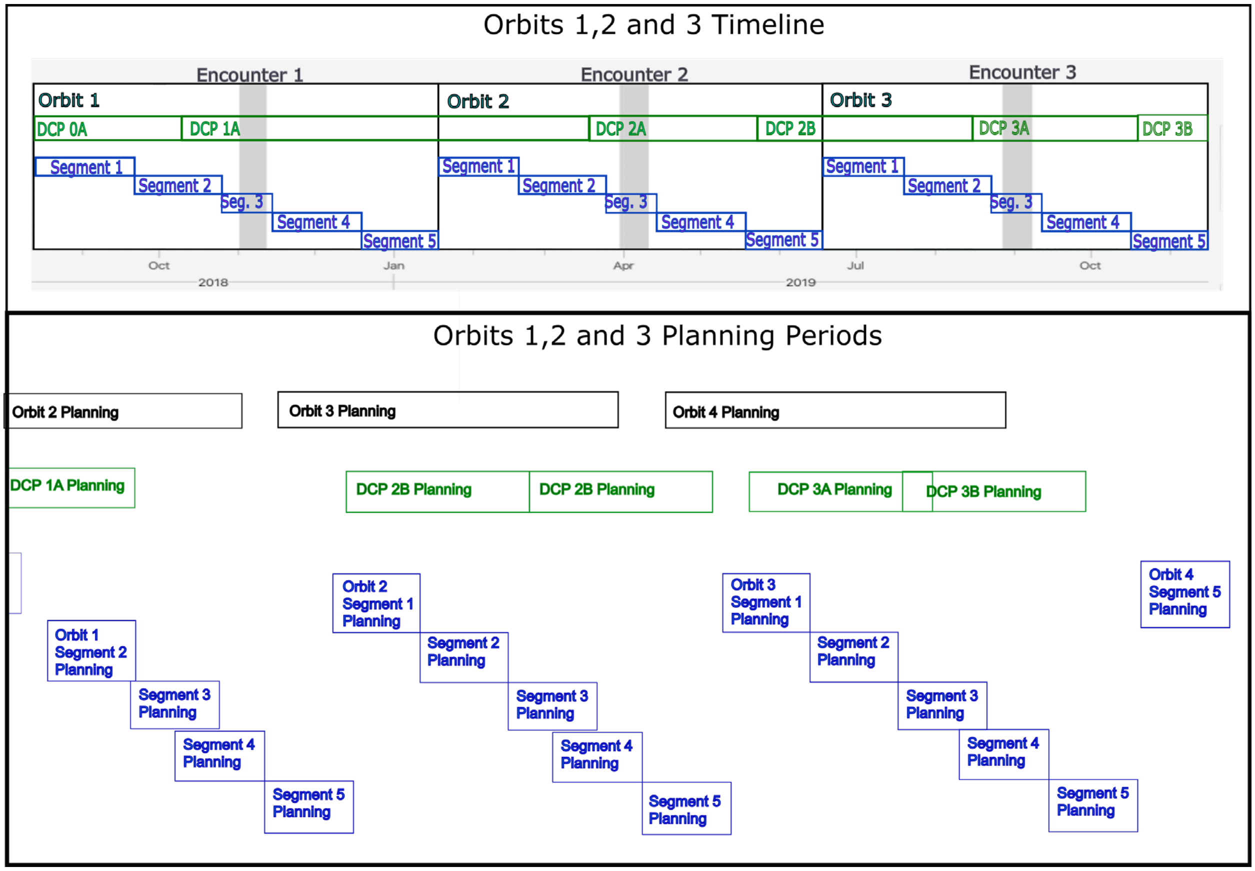

Figure 7.1.5 a: The top of the figure shows the timeline of the first 3 orbits and the DCP and orbit segment periods. The bottom of the figure shows the orbit, DCP and orbit segment planning process periods. The orbit planning periods are performed from -28 to -10 weeks before the start of the orbit. The DCP planning periods are performed from -12 to -2 weeks from the start of the DCP. The orbit segment planning periods are performed from -4 weeks to -3 days from the start of the orbit segment.

Figure 7.1.5 a displays the actual time periods that orbit, DCP and orbit segment cover on the top and the planning periods below. Depending on the length of the orbit, DCP or orbit segment, planning periods may overlap. When planning steps overlap or occur around holidays, MOPS and the SPL shift activities and due dates to balance the workload appropriately since there is margin in the schedules.

7.1.5.1 Orbit Planning Team

The Orbit Planning Team (OPT) is comprised of MOPS, DSN Scheduler, Project Science team, the Science Planning Team Leads (SPL) and the Payload Planning Leads (PPLs).

The Science Planning Team (SPT) is comprised of the Project Science team, the SPL, and the PPLs.

The SPL leads production of the conflict resolved PASF and the PPL leads production of the individual team PASF. They work together with MOPS to deliver a conflict resolved product.

7.1.5.2 Orbit Planning Steps Schedule

The Orbit planning steps shown in the figure 7.1.5.2 a, display the planning steps performed in the weeks relative to the start of orbits 3 and 4. Depending on the orbit period length, planning steps may overlap.

The Orbit Planning Steps Schedule table shows the planning steps performed in weeks relative to the start of the orbit. The steps involving SPL, Project Science or PPL are defined further.

Orbit Planning Steps Schedule		
Date (Relative to Orbit Start)	**Performed By**	**Task**
-28 weeks	MOPS	Initial DSN Contact Requirements Delivered to DSN Scheduler
–25 weeks	DSN Scheduler	Long Range DSN Schedule Delivered to MOPS
–24 weeks	MOPS	Define Orbit X Segments
–24 weeks	MOPS	Initial OAF Delivered to the Orbit Planning Team
–23 weeks	All	Orbit X Planning Kick-Off meeting
–16 weeks	SPT	Special Tests or Non-Routine Activities Requiring Instrument & Spacecraft coordination Identified and List given to MOPS
–15 weeks	SPT	Priority of non-routine requests defined (SPT)
–14 weeks	OPT	Orbit Planning Team proposes adjustments to the DSN Contact Requirements or Orbit Segments
–14 weeks	MOPS	Updated Contact Requirements Delivered to DSN Scheduler
–12 weeks	DSN Scheduler	Updated Long Range DSN Schedule Delivered to MOPS
–12 weeks	MOPS	Updated OAF Delivered
–10 weeks	SPT	Full Orbit PASF Delivered
–10 weeks	MOPS	Updated OAF Delivered
–10 weeks	MOPS	Create the Orbit X Segment Planning Schedule

Define Orbit X Segments
The delivery of the orbit segments to the OPT allows the SPL to generate the detailed orbit segment PASF merge schedule for the Payload teams.

Special Tests or Non-Routine Activities – These out of the ordinary instrument and spacecraft activities are delivered to Mission Operations early in the schedule for evaluation and possible approval by spacecraft teams and project management prior to scheduling. Priority for these events are set during orbit planning meetings.

Orbit Planning Team proposes adjustments to the DSN Contact Requirements
The deposition of science data to the spacecraft SSR and the availability of science Ka-band downlink passes are critical for this mission. The SPL, with help from the Project Science team and PPL, will use SPADER to model the orbit data downlink and recommend to MOPS if we need to move or get additional passes to accommodate the data downlink requirements. The adjustment takes into account the need for high or low speed transfers for FIELDS, SWEAP and

WISPR. MOPS will collect all spacecraft subsystem pass recommendations and negotiate with the DSN to get the final DSN schedule. This step is part of the Data Collection Period Planning discussed in a later section.

Full Orbit PASF Delivery
The activities included in a PASF can cover one orbit segment or a full orbit. Early in the planning schedule, a full orbit PASF is produced by the payload teams to give MOPS a view into major planned payload activities. Later in the orbit segment planning process, the PASF activities only cover the segment being planned. One week is allowed for merge and conflict resolution of the full orbit PASF.

The planning process for the full orbit PASF was updated to not include power on and off activities. At the delivery time of the full orbit PASF, the DSN pass times are too preliminary to justify scheduling power on and off activities.

Updated OAF Delivery
If a PASF has already been delivered and a new OAF contains a change to the DSN schedule the delivered PASF will be updated and redelivered unless MOPS needs to do it due to time constraints.

7.1.6 Data Collection Period Planning

Each period of science data acquisition and science data downlink is organized into a data collection period (DCP); this period is determined primarily by how much science data can be stored—and downlinked from—the spacecraft solid state recorder (SSR). The start of a DCP occurs when the Record Allocation Table (RAT) onboard the spacecraft is reset, which allows more science data to be stored on the spacecraft SSR. This so-called "RAT reset" occurs shortly after an extended period of science downlink when most or all of the science data on the spacecraft SSR has been downlinked and the SSR resources taken up by this downlinked data have been freed.

Depending on the PSP-Sun-Earth geometry for a given orbit, it may be possible to have multiple DCPs. This occurs because there is: 1) sufficient downlink capability to support more science data the spacecraft SSR can store, and 2) sufficient time to acquire and/or transfer science data from the instruments to the spacecraft SSR outside of the encounter region. To account for this possibility, DCPs are labeled by two-digit orbit number (nn) of the orbit of the RAT reset, and a single letter designation beginning with "A." DCPs containing an encounter region will have the "A" designation whether or not there are multiple DCPs in that particular orbit. The DCP A periods typically use the data priority table shown in figure 7.1.b.

When there is a second DCP "B" in the orbit, the percentages for the FIELDS and SWEAP teams for priority 4 are moved to priority 7 or 8 to allow for the ISOIS and WISPR data in priority 6 to come down before the FIELDS and SWEAP data.

7.1.6.1 Data Collection Period Planning Teams

The Data Collection Period Planning Team is comprised of the Project Scientist, SPL and MOPS. Data distribution to the instruments are fine-tuned with the Payload Primary Investigators.

7.1.6.2 Data Collection Period Planning Steps Schedule

The DCP Planning Steps Schedule table shows the planning steps performed in weeks relative to the start of the DCP or the PASF due date.

The start of the DCP is the date of DCP Record Allocation Table (RAT) load and setting the RAT to 0 allows the instruments to record more data to the spacecraft SSR.

DCP Planning Steps Schedule		
Date	**Performed By**	**Task**
-12 weeks from DCP start	PS & Payload Teams	Preliminary DCP Data Volume Delivery
-3 weeks from PASF due date *	PS & Payload Teams	Negotiated DCP Data Volume Delivery
-2 weeks from DCP start	MOPS	Final DCP Data Volume Delivery

Preliminary DCP Data Volume Delivery

The SPL will obtain the maximum safe SSR usage for the DCP from MOPS. The SPL and the Project Scientist work together to generate the preliminary data volumes for the individual payloads. The plan should contain contingency plan for loss of DSN passes for critical data downlink passes. Part of the preliminary data volume task is to propose adjustments to the DSN Contact Requirements that is a step of the Orbit Planning Process. The Appendix Data Volume includes the launch data volume.

During the DCP Data Volume planning, if a need is identified for FIELDS and SWEAP high speed transfers, the team should verify that the “survey data” written to the spacecraft solid state recorder (SSR) will downlink with enough time for analysis to select “selected data” during the DCP. They should also verify that command uplink schedule allows commanding when needed to transfer instrument SSR data to the spacecraft SSR and that that the “selected data” will be written to the spacecraft SSR within the data utilization cycle and with enough downlink schedule without a significant adverse effect on the subsequent orbit

The SPL will combine these DCP data volumes with the default data priority percentages for the type of DCP to generate the Data Volume Priority System File (DVPS). The data volumes alone are used to generate the Payload Data Volume (PDV) file. These files are delivered to the teams science planning section on the MOC data server.

Negotiated DCP Data Volume Delivery

The negotiated DCP data volumes are a product of the negotiations between the Project Scientist, MOPS and the payload teams. The DVPS and PDV are updated with the new numbers and delivered to the teams science planning section on the MOC data server.

Final DCP Data Volume Delivery
MOPS delivers the final data volume to use taking into account any necessary reduction in data volume. The DVPS and PDV are updated with the new numbers and delivered to the teams science planning section on the MOC data server.

7.1.7 Orbit Segment Planning

The Orbit Segment Planning section covers the individual orbit segment planning process. This process is performed multiple times an orbit and will overlap with the other segment planning processes.

7.1.7.1 Orbit Segment Planning Teams

The Orbit Segment Planning Teams are the same as the Orbit Planning Teams.

7.1.7.2 Orbit Segment Planning Steps Schedule

The Orbit Segment Planning Steps Schedule table shows the planning steps performed in weeks relative to the start of the orbit segment.

Orbit Segment Planning Steps Schedule		
Date (Relative to Segment Start)	**Performed By**	**Task**
-4 weeks	SPL & Payload Teams	Segment X PASF Merge Process
-3 weeks	SPL & Payload Teams	Segment X PASF Conflict Resolution
-2 weeks	SPT	Segment X Final Merged PASF Delivered
-2 weeks	G&C	Segment X Final SASF Delivered
-1.5 weeks	MOPS	Segment X Time Tag Load Built & Timeline Distributed
-8 days	Payload Teams	Segment X Timeline Formal Approval Delivered
-1 week	MOPS	Segment X SPPOPS Testing
-3 days	MOPS	Segment X Time Tag Load Uplinked to Spacecraft

Since these steps are keyed to the start of the orbit segment, there may be some overlap between steps from one orbit segment to the next.

Segment X PASF Merge Process
The PPL creates their instruments PASF. Their PASF (and the command load created later in the process) should satisfy the proposed Payload data volume rate and priority.

The PPL should communicate any DSN & MOPS real-time support needs during the PSP Operations Planning meeting in addition to scheduling upload activities in the PASF. They should verify that command uplink schedule allows for command loads and larger loads like instrument flight software should have back up passes for contingency. Larger command loads like flight software loads should have been identified during the Special Tests or Non-Routine step in the Orbit Planning Steps Schedule. Management of these non-routine steps is also done during the Operations Planning Meetings.

During the PASF merge process, each team adds their PASF activities to a merge PASF and passes it along to the next team by use of the MOC Data Server Teams planning area. Combining the PASFs is done using the PASF Merger.

The typical merge order of FIELDS, SWEAP, ISΘIS and WISPR was established to allow the FIELDS and SWEAP teams to schedule their high speed transfers first before the other teams added their activities. Depending on the special activities planned for the segment, a different merge order may be selected during the orbit planning process. Four days are allowed for the segment X PASF merge process.

Segment X PASF Conflict Resolution

After the payload teams have merged their activities, the SPL staggers the activities around the blackout periods, imposes MOPS required margins and reorders the power on and off activities in an OPT approved order to maximize power on time for instruments with slower warmups.

The SPL works with the individual payload teams to resolve any issues and posts the conflict free PASF to the MOC Data Server Teams planning area for approval by the payload teams. Once approval from all the PPLs is received, the PASF is delivered to MOPS. Five days are allowed for the conflict resolution process.

Conflict resolution for instrument activities includes finding and correcting the following conflicts:

1. Conflicts with spacecraft blackout periods such as those defined for Ka-band downlink passes; no instrument can be powered on during a Ka-band downlink pass.
2. Conflicts with FIELDS and SWEAP high data rate transfer periods; only ISΘIS can be powered on when either FIELDS or SWEAP are making their high data rate transfers.
3. Conflicts with other instrument activity durations; no two instrument activities that call spacecraft macros can execute at the same time. The spacecraft macro execution times are on the order of seconds.
4. Incorrect separation of instrument activities as required by MOPS required margins and buffers.

Segment X Time Tab Load Build & Timeline Distributed

Once the PASF is received by MOPS, it is loaded into the OAF and any timing issues with spacecraft activities are resolved. If issues arise, an updated PASF with the necessary changes is created and delivered to the MOC data server. The Time Tag Load is built and the timeline is delivered to the MOC Data Server in an area available to the payload teams.

Segment X Timeline Formal Approval Delivered
The payload teams review the timeline and send approval to MOPS via email.

7.1.8 Payload Team Orbit/Orbit Segment Planning

The following sections describe payload planning practices for orbit and orbit segment planning.

7.1.8.1 FIELDS

FIELDS SOC personnel participate in the Orbit Planning Process, which coordinates activities among the payload and spacecraft teams and generates high level science goals for individual encounters. FIELDS will use input from the planning process as well as planning products available from the MOC to plan observing modes and data collection rates for a given encounter. An ATS (Absolute Time Sequence) reflecting these priorities will be created and tested prior to the encounter. The ATS is built from a GSEOS-compatible Python script, and tested using a GSEOS-compatible test script, which accelerates the test from 10-12 day encounters to 4 to 8 hours on the engineering model (EM). The test procedure will "jump the mission elapsed time (MET)" in a manner similar to the time jumps used during I&T, in order to verify the proper instrument configuration and telemetry rates.

7.1.8.2 IS⊙IS

IS⊙IS will create software to plan operations, visualize operations performed in different parts of the orbit, identify times of interest (such as conjunctions), and periods where telemetry is gathered at different rates.

7.1.8.3 SWEAP

See Section 3.4.2 (description of the SWEAP Instrument Commanding and Operations (ICO portion of the SWEAP SOC).

7.1.8.4 WISPR

WISPR personnel utilize the WISPR Heliospheric Imager Planning Tool (WHIPT) to model observation plans and translate them to schedule files that are uploaded to the WISPR IDPU. The WISPR team is also developing an IDL-based tool to visualize the orbit of PSP and other missions (e.g., Solar Orbiter), to search for times of interest and to plot the passage of targets through the WISPR field of view. The early version of the software is already in use by members of PSP SWG.

While observations from other Heliophysics missions are not required to achieve PSP Level-1 science objectives, it is advantageous to be able to augment the science by using data from other missions, both space based and ground based. In particular, it is desirable that the mission knows when the spacecraft will be in conjunction with other suitable missions so that the instrument teams can plan burst campaigns. The Science Planning Tool will also be used to determine the periods of conjunction. We use the term "conjunction" to denote a time when the relative locations of PSP and another mission are scientifically interesting. This could be a spatial location (i.e. the spacecraft are located on the same magnetic field line), or a temporal location such that one mission is located in a source region while the other is in the target region while studying the same temporal event.

7.1.9 Payload Team Command Generation

Command generation is performed over weeks 2 – 0 before execution of the orbit segment and the products generated cover all or part of an orbit segment. Command files must be delivered to the MOC at least 15 minutes before an uplink opportunity as is stated in the 7434-9078 SPP MOC to SOC ICD. Each payload SOC use Ground Support Equipment Operating System (GSEOS) to put one to many command packets into the Instrument Supplemented Command File (ISCF) and deliver it to the MOC for uplink to the spacecraft. See figure 3 a in section 3 for a data flow diagram including commanding.

7.2 Roles and Responsibilities

This section describes the roles and responsibilities of PSP team members during the orbit planning process.

7.2.1 Initial Orbit

These are the duties that should be performed before Orbit Planning begins

Science Planning Team Leads (SPL)

1. Work with MOPS to generate schedule for orbit segment planning and update MOC Data Server Team Planning site.

Science Gateway System Engineer

1. General engineering support for the website.
2. Update Science Gateway with new SPICE kernels

Payload Scientists

Generate individual instrument Science Priorities and coincident opportunities inputs. Notify MOPS of any changes to activities or special orbit

SPTool

The SPADER Lead Engineer is responsible for providing engineering support for SPADER throughout planning cycle.

7.2.2 Data Collection Period Planning

Chair – Project Science

1. Work together with SPL and MOPS to obtain maximum safe SSR usage for DCP
2. Project Science and SPL propose adjustments to the DSN Contact Requirements
3. SPL responsible for generating instrument data volume. PS has final responsibility for data allocation determination.
4. Responsible for delivery of data volume product to MOC Data Server

7.2.3 Orbit & Orbit Segment Planning

Chair – MOM or DMOM (deputy MOM)

Plan, coordinate, and manage meeting process, with the leadership role.

MOPS

1. MOPS is responsible for defining DSN contact requirements and communicating them to SSMO.
2. MOPS is responsible for collecting the long-term, updated and final DSN schedules from SSMO and delivery to the MOC.
3. MOPS is responsible for delivery of an updated OAF for S/C activities and DSN activities to the MOC.
4. MOPS is responsible for delivery of a list of conflicted activities from the latest S/C and DSN activities to the MOC and the SPT.
5. MOPS coordinates the use of uplink availability by Spacecraft and Payload teams.
6. MOPS includes Spacecraft Engineering (SE), Navigation (NAV), and Mission Design (MD), Space Science Mission Operations (SSMO) as needed.

SPL

1. Participate in meetings if payload activities are contained within. Provide conflict resolution decisions**.**
2. Perform conflict resolution on merged PASF
3. Perform any needed adjustments to PASF not performed by PPLs.
4. Responsible for delivery of adjusted and approved orbit segment and full orbit PASFs to MOC.
5. Obtain payload PASF and MOC products
6. Get final approval from PPL.
7. Responsible for delivery of merged conflict free orbit segment PASF to MOPS
8. Responsible for working with PPL to respond with last minute updates needed by MOPS or PPL

PPL

1. The PPLs are responsible for participation in the meetings that cover orbit segments in which they have activities.
2. The PPSs are responsible for delivering notice of any special tests or non-routine activity's requiring instrument and spacecraft coordination.
3. The PPLs are responsible for delivery of the initial PASF to the MOC Data Server planning site.
4. The PPLs are responsible for providing uplink requests either through the PASF, email or verbal notice during planning meetings.
5. The PPLs will participate in the merging of the instrument activities.
6. The PPLs are responsible for adjustment of activity times and generation of updated PASF as needed to resolve conflicts and the generation of updated instrument PASF when needed.
7. PPLs are responsible for performing any re-checking of instrument constraints that are required by moved instrument activity times.

Orbit Segment Planning Conflict resolution decision process - Majority vote with Science Planning Team Lead having the final decision authority however, major issue resolution would be dealt with at PS level.

7.2.4 Payload Command Generation

Chair – Payload Planning Team Lead (PPL) (Instrument SOC Lead **or designee)**

1. PPLs are responsible for designing this step and it is performed at the remote SOC locations.
2. PPLs are responsible for generating the initial payload PASF to be used in activity planning.

MOPS is responsible for delivery of spacecraft command files to the MOC.
PPLs are responsible for delivery of payload command files to the MOC.

8 APPENDIX: ACRONYMS, ABRIEVATIONS AND DEFINITIONS

APID	Application Process Identifier
ASCII	American Standard Code for Information Exchange
CCSDS	Consultative Committee for Space Data Systems Space Packet Protocol
CDAWEB	Coordinated Data Analysis Web
CDF	Common Data Format
Co-I	Co-Investigator
CONOPS	Concept of Operations
CTG	Command Telemetry and GSE
DCP	Data Collection Period. The DCP is disconnected from the orbit and encounter time periods. It goes from the reset of the instrument on board allowed data volume to the next reset.
DSN	Deep Space Network
Encounter	Defined when the spacecraft is within 0.25 AU distance to the Sun
EM	Engineering Model
FIELDS	FIELDS instrument suite
FITS	Flexible Image Transport System
FTP	File Transfer Protocol
GSE	Ground Support Equipment
GSEOS	Ground Support Equipment Operating System
GSFC	Goddard Space Flight Center
HeliOSPP	Heliospheric origins with Parker Solar Probe: The Observatory scientist (OS)
HTTP	Hypertext Transfer Protocol
I&T	Integration & Test
ICD	Interface Control Document
IDL	Interactive Data Language
IS⊙IS	Integrated Science Investigation of the Sun
ISTP	International Solar Terrestrial Physics
JHU/APL	Johns Hopkins University Applied Physics Laboratory
NSSDC	National Space Science Data Center
MET	Mission Elapsed Time

MIDL	Mission Independent Data Level
MOC	Mission Operation Center
MOCR	Mission Operations Change Request
MOPS	Mission Operations
MRD	Mission Requirements Document
NASA	National Aeronautics and Space Administration
NRL	US Naval Research Laboratory
OAF	Orbit Activity File (ASCII file containing spacecraft activities and eventually payload activities merged from the PASF)
OPT	Orbit Planning Team (MOPS, Mission Design, NAV, S/C Engineering, DSN, PS, PPT, SPL, SPTool)
Orbit	Aphelion to Aphelion
Orbit Segment	The orbits will be divided up into smaller contiguous parts called orbit segments. These segments will be variable in length and will be designed to cover specific spacecraft or instrument activities, like the pre-encounter period or encounter.
PASF	Payload Activity Sequence File (ASCII file containing timeline of payload supported activities for communication to MOPS)
PI	Principal Investigator
PPL	Payload Planning Team Lead – SOC Lead or designee
PPT	Payload Planning Team, PPL and payload planning team members as identified.
Payload Scientists	PI, SOC Lead or designated representative
PS	PSP Project Scientist
PSP	Parker Solar Probe
RAID	Redundant Array of Inexpensive Disks
SAO	Smithsonian Astrophysical Observatory
SCM	Search Coil Magnetometer
SDC	Science Data Center
SDAC	Solar Data Analysis Center
SPADER	Science Planning Analysis and Data Estimation Resource. This is the PSP science planning tool.
SDMP	Science Data Management Plan
SPL	Science Planning Team Lead

SSH	Secure Shell
SO	Solar Orbiter
SOC	Science Operation Center
SOH	State Of Health
SPASE	Space Physics Archive Search and Extract
SPDF	Space Physics Data Facility
SPEDAS	Space Physics Environment Data Analysis Suite
SPT	Science Planning Team (PS, SPL, PPT, SPTool)
SPTool	SPADER software engineer
SQL	Structured Query Language
SSMO	Space Science Mission Operations, NASA Goddard (PSP Deep Space Network Scheduling Team)
SSR	Solid State Recorder
SWEAP	Solar Wind Electrons Alphas and Protons Investigation
SWG	Science Working Group
SWRI	Southwest Research Institute
TBD	To Be Determined
TCP/IP	Transmission Control Protocol/Internet Protocol
UCB	SSL UC Berkeley Space Sciences Laboratory
UMN	University of Minnesota
UNH	University of New Hampshire
UTC	Universal Time Coordinated
VNC	Virtual Network Connection
VO	Virtual Observatory
VHO	Virtual Heliospheric Observatory
WISPR	Wide-field Imager for Parker Solar Probe
XML	Extensible Markup Language

The launch data volume used on PSP is included below in figure 9 a.

Payloads	Data Volume (Gbits)
FIELDS	29.5
SWEAP	29.5
EPI-LO	13.7
EPI-HI	4.3
WISPR	30
Total	107

Figure 9 a: Launch payload data volume.

10 APPENDIX: PSP SCIENCE GATEWAY

The Gateway was developed using "Drupal", an open-source content management system (http://drupal.org). The usage of Drupal allows registered users to contribute new material and greatly simplifies the maintenance of the site. Although registration is not required to access most of the content of the Gateway, we strongly encourage users to register using the "Create Account" button at the top of the page to take full advantage of all its content.

The URL for the Science Gateway is https://sppgway.jhuapl.edu/ and the front page on the Science Gateway is illustrated below:

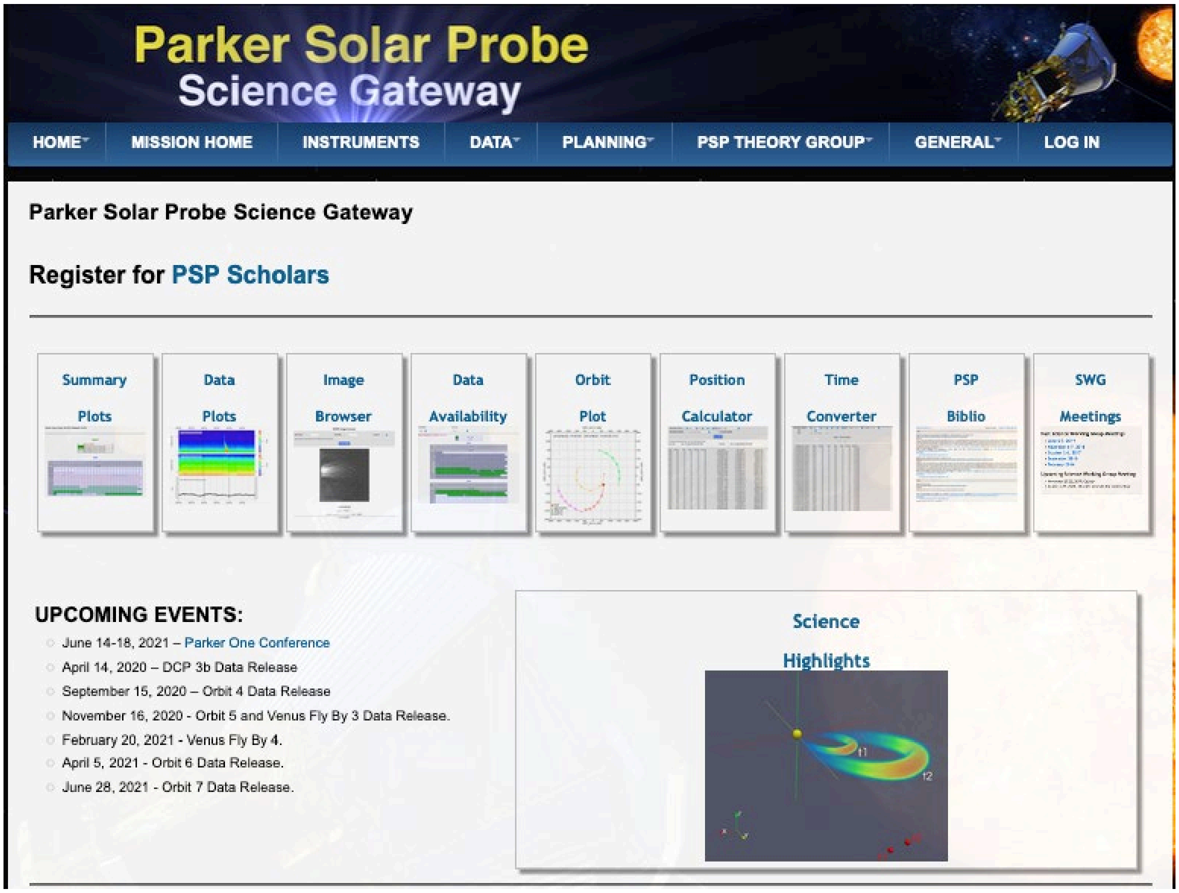

Figure 9 a: PSP Science Gateway main page.

The page contains a main menu at the top of the page, and shortcut links for the most used tools in the form of clickable icons/buttons.

10.1 Data Plotting Utilities

The following sections describe the data plotting utilities available on the PSP Science Gateway. Please add the proper acknowledgement when using these data. For further assistance, please contact the PSP Instrument teams involved.

10.1.1 Summary Plots

The Summary Plot shown in the left of the figure below, allows users to easily visualize intervals when instruments are ON. Clicking on the day will display a pre-generated multi-instrument plot for that day, which is shown on the right of the following figure.

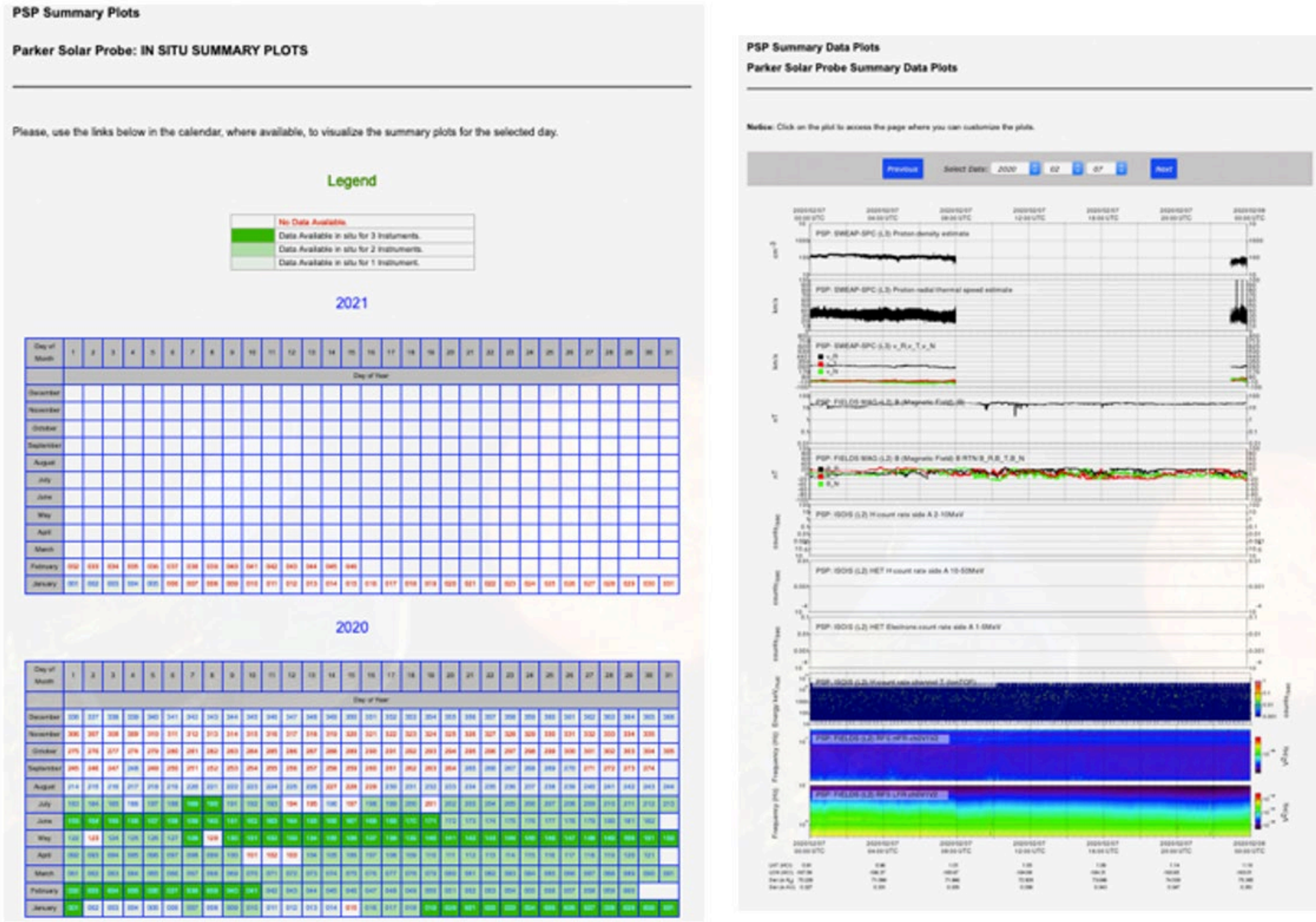

Figure 9.1.1 a: The Summary Plot is on the left and the pre-generated multi-instrument plot is on the left.

10.1.2 Data Plots

Users can generate customizable line plots or spectrograms through a web interface. Users can also save their plots as PDF, PNG, or as a URL link to be used later to retrieve their work.

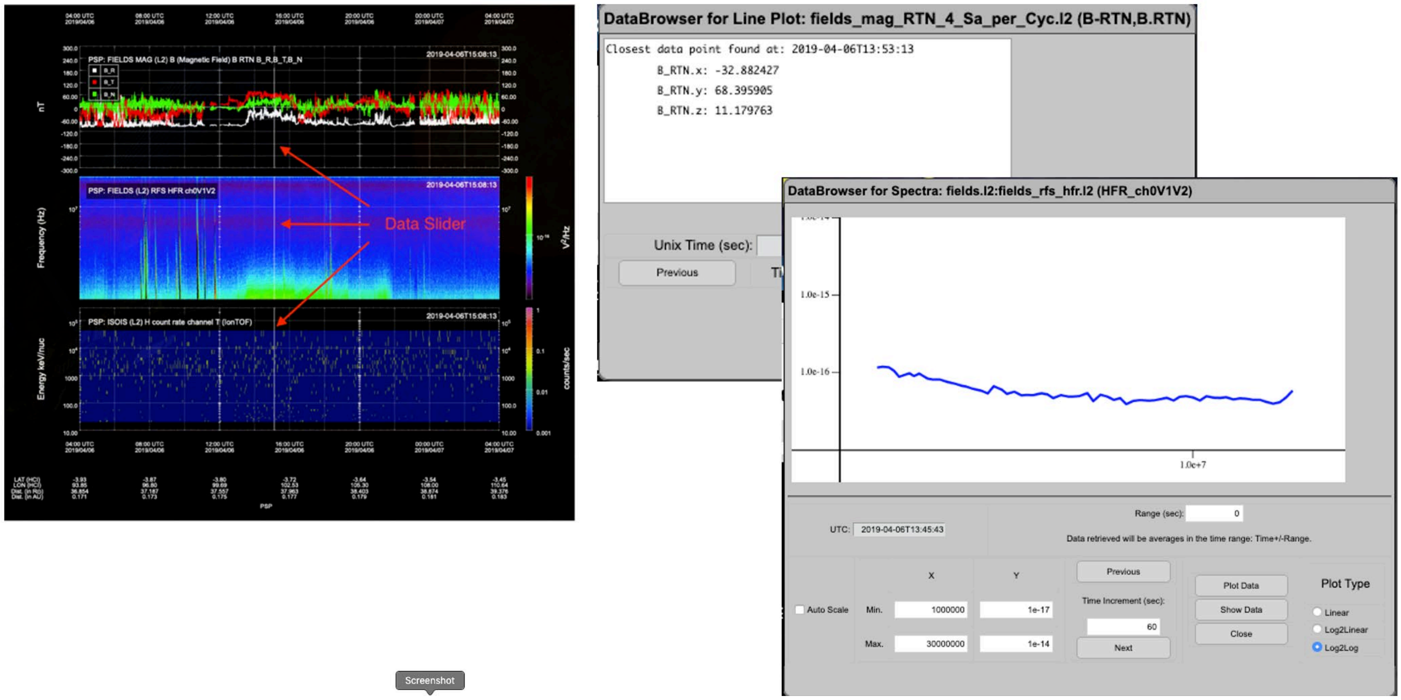

Figure 9.1.2 a: Data Plots displaying the Data Slider which slices through the data, in all plots, at the selected time when the user hovers with the mouse. The closest point found and spectra dialogs show the closed data point to the data slider and the spectra.

10.1.3 Image Browser

The Image Browser displays the WISPR Image Gallery. For further assistance, please contact the WISPR team. The figure below shows the browser interface with the start and stop date and the camera selection.

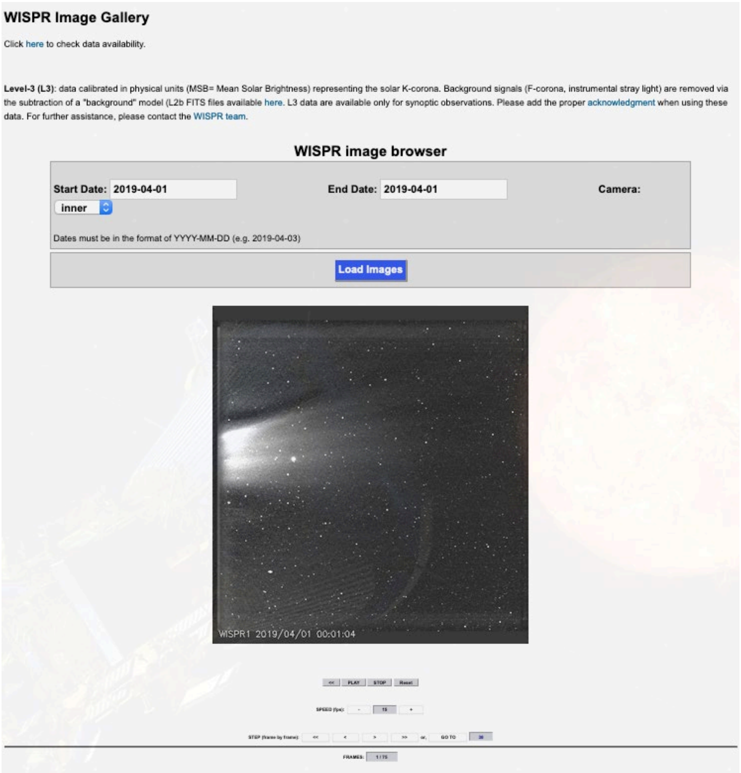

Figure 9.1.3 a: WISPR Image Gallery.

10.1.4 Data Availability

The Data Availability displays color coded calendar days when data are available for a selected instrument as is shown in the figure below. Clicking on the day brings up the selected instrument data in an customizable plot.

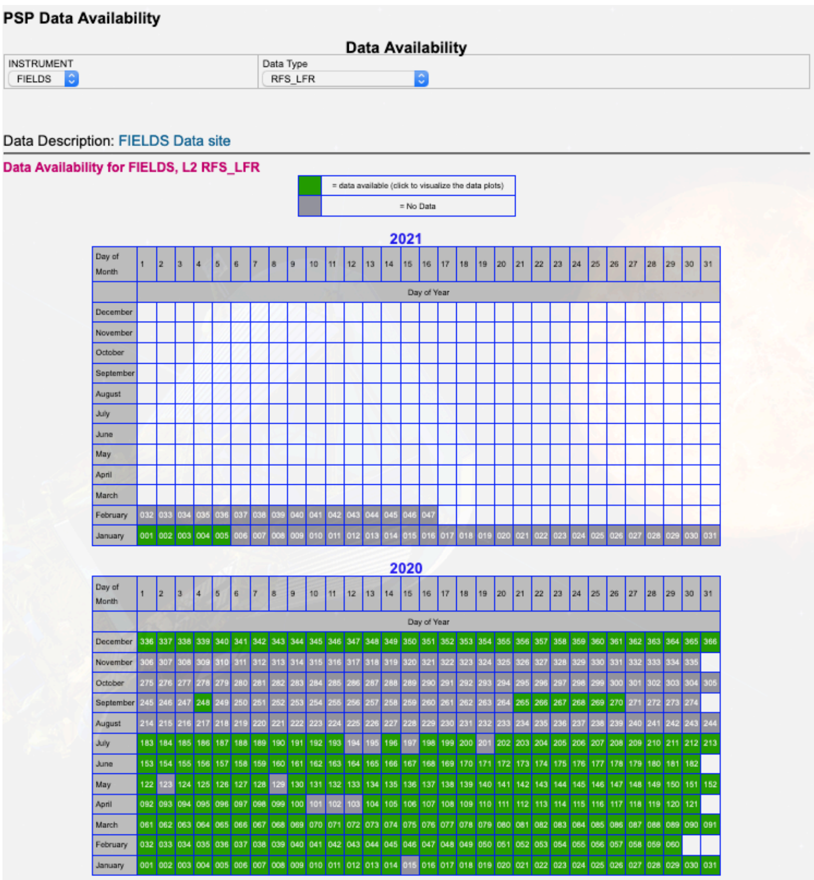

Figure 9.1.4 a: Data Availability Plot showing FIELDS L2 RFS_LFR data.

10.2 Planning Tools

10.2.1 Orbit Plot

The Orbit Plots are available in two different versions, 2D and 3D. They will display PSP, and other celestial bodies, spacecraft and their orbits.

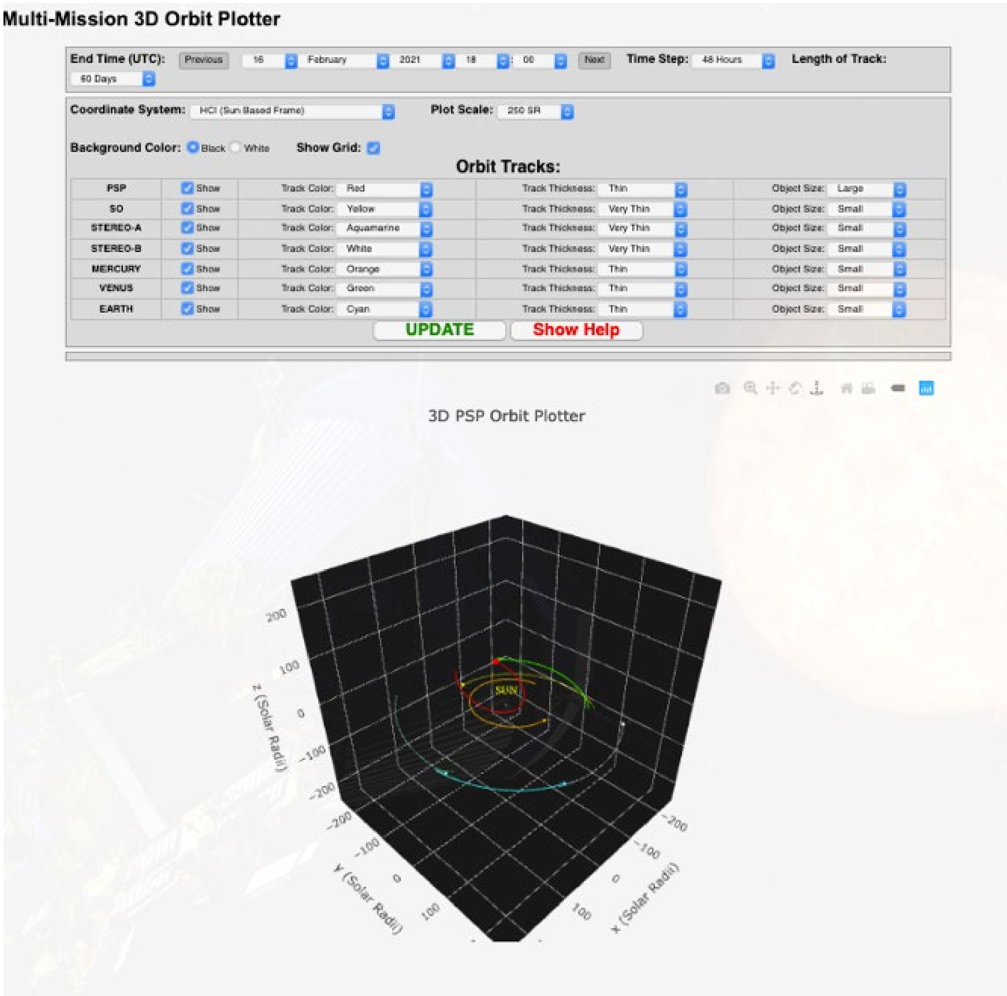

Figure 29.2.1 a: 3 D Multi-Mission Orbit Plot. The plots are customizable by time, coordinate frame, and contents.

10.2.2 Position Calculator

Displays PSP position in several coordinate frames for selectable intervals of time using predict ephemerides for future positions.

10.2.3 Time Converter

Allows users to convert time between Coordinated Universal Time (UTC) to Spacecraft Clock Time (SCLK). The time range and cadence are selectable and the output can be written to an ASCII file.

10.2.4 PSP Biblio

Parker Solar Probe bibliography, maintained on a monthly basis, is a searchable tool that allows users to look for published papers related to Parker Solar Probe mission and science

11 APPENDIX: PLANNING TOOLS

This section describes the mission planning tools that are important to the science planning process.

11.1 Activity Planner

To facilitate the orbit planning process, PSP is utilizing an APL developed software tool called Activity Planner. Activity Planner allows an orbit planner to ingest pertinent information related to each orbit, such as the DSN contact schedule, orbital events and data related to orbital geometry, and allowable uplink and downlink rates for each DSN contact. With this information, Activity Planner can automatically schedule routine activities such as configuring the RF system prior to a DSN contact. It allows mission operators to plan and configure commanding of the spacecraft both in and out of contact with a ground antenna.

Activity Planner exports executable contact plans, ground station configuration and other informational data products for consumption of downstream applications. In addition, the orbit planner can fold in other planned spacecraft activities and view visual orbit activity timelines.

Activity Planner generates the OAF which contains activities like downlinks, power on opportunities, command uplink opportunities and payload activities for a specific orbit. Activity Planner inputs the PASF from the instruments and outputs an OAF containing both spacecraft and instrument activities.

11.2 SPADER

SPADER was developed to facilitate science planning, and has three distinct operating modes: mission data simulator, orbit plot visualizer, and payload activity sequence file (PASF) merger. This combined suite of tools helps facilitate long range planning, science observation prioritization and cross-mission collaboration, and short-range instrument activity deconfliction.

SPADER has the following capabilities;

- Facilitate selection of the instrument data volume and priority scheme that works best for the current orbit and allow predictions of best values for future orbits.
- Facilitate identification and correction of instrument activity conflicts. See section 7.2.3.1 Activity Conflict Resolution for more details on conflicts.
- Allow for the collection and merge of instrument activities and production of the orbit segment PASF that is a combined and conflict free listing of instrument activities.
- Suggest the inclusion of unused but available DSN downlink passes for an orbit to better facilitate science downlink.
- Facilitate the identification of coordinated observation times with other missions. There will be a display indicating periods when PSP can have coordinated observations with other space missions (e.g. Solar Orbiter) and ground-based observatories.

11.2.1 Mission Data Simulator

The mission data simulator is designed to model long-term effects on data production, SSR usage and file downlink due to collective contributions from spacecraft housekeeping, instrument data generation policies and DSN availability. The simulator models data flow from packet generation to SSR file generation to file downlink using a time-averaged packet model that closely follows the flight-software model of PSP. The SPADER development team has collaborated with MOPS, the PSP Radio Frequency Team and the PPLs to create the models. Figure 7.1a shows an example of the output of the mission data simulator and the breakdown of data volume across the various spacecraft and instrument data sources.

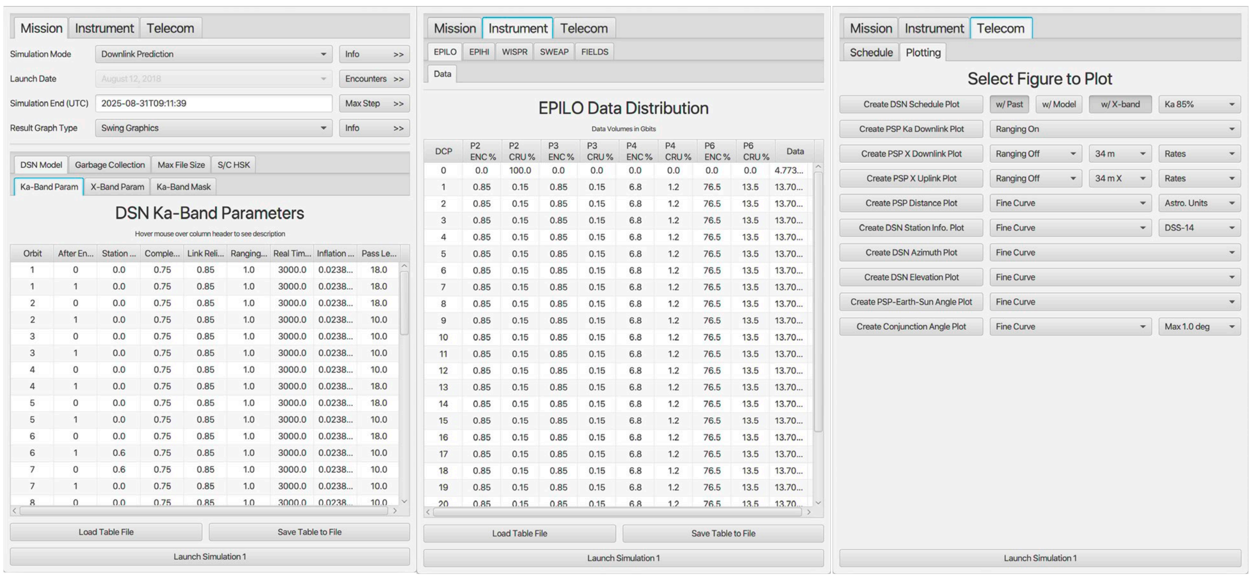

Figure 10.2.1 a: Left: The "Mission" tab of the SPADER mission data simulator graphical user interface configuration window. Center: The "Instrument" tab showing the data volume distribution of one instrument for each data collection period. Right: The "Telecom" tab showing options for plotting many different parameters relation to data uplink, downlink, and telecommunications.

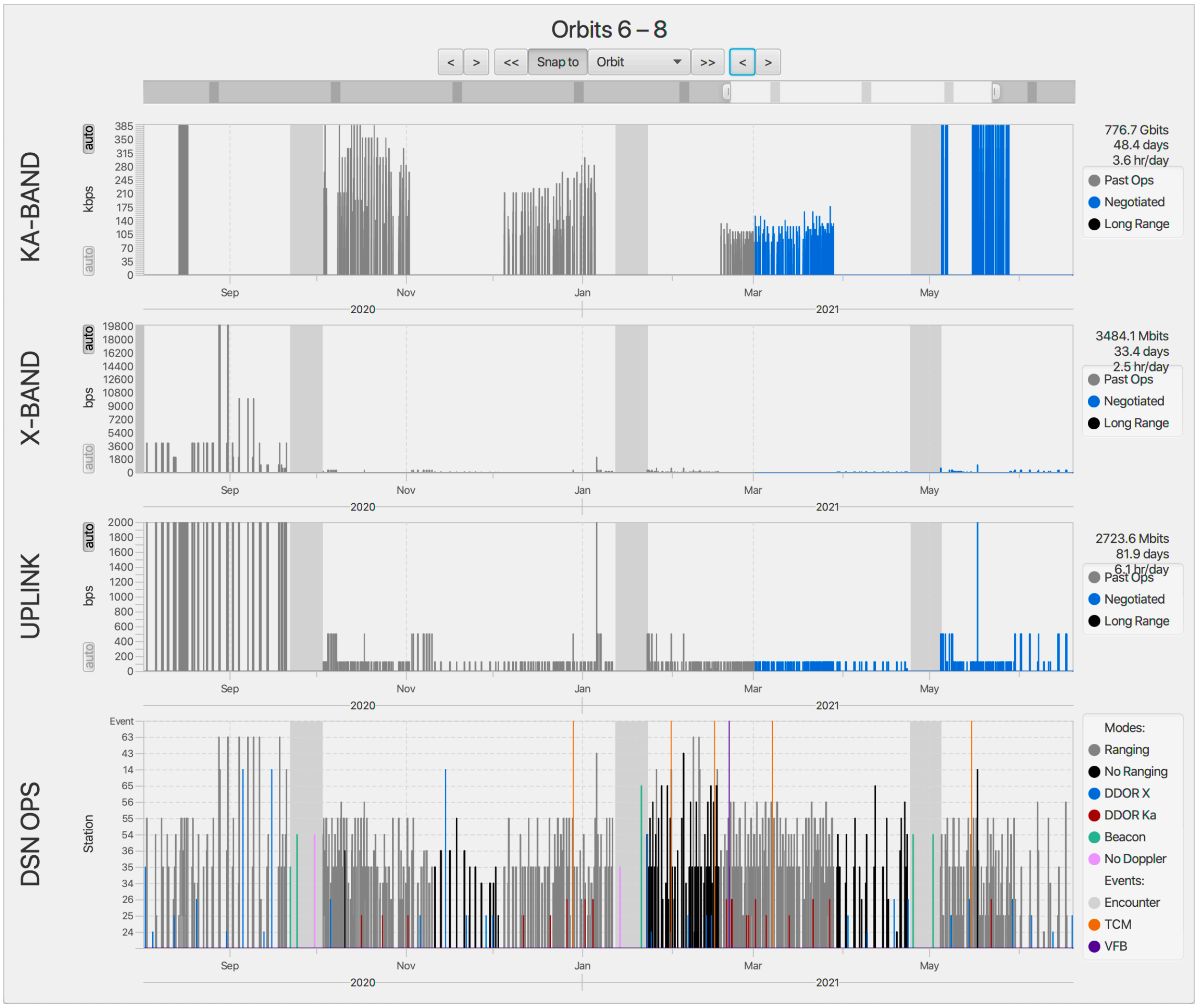

Figure 10.2.1 b: The DSN Schedule Plot generated via the "Telecom" tab of the configuration window. This is an interactive figure that graphically shows telecommunications operations for the mission, as well as downlink and uplink data volumes for any period of interest.

The SPADER mission data simulator is highly configurable using both file-based input and graphical user interface input. It initialized with conservative science data volumes for the mission, but can be updated and loaded with values that more accurately represent the capability and expectations of the mission.

11.3 Orbit Plot

The orbit plot visualizer is an interactive to-scale representation of the inner solar system and heliophysics space missions. It is both a dynamic visualization of the locations of PSP, STEREO, Solar Orbiter, BepiColombo, the sun and all planets up to and including Jupiter, and a static visualization of the orbital trajectories of these spacecraft and celestial bodies. It has the capability of plotting in eight different coordinate systems commonly used in heliophysics, including corotating heliographic coordinates.

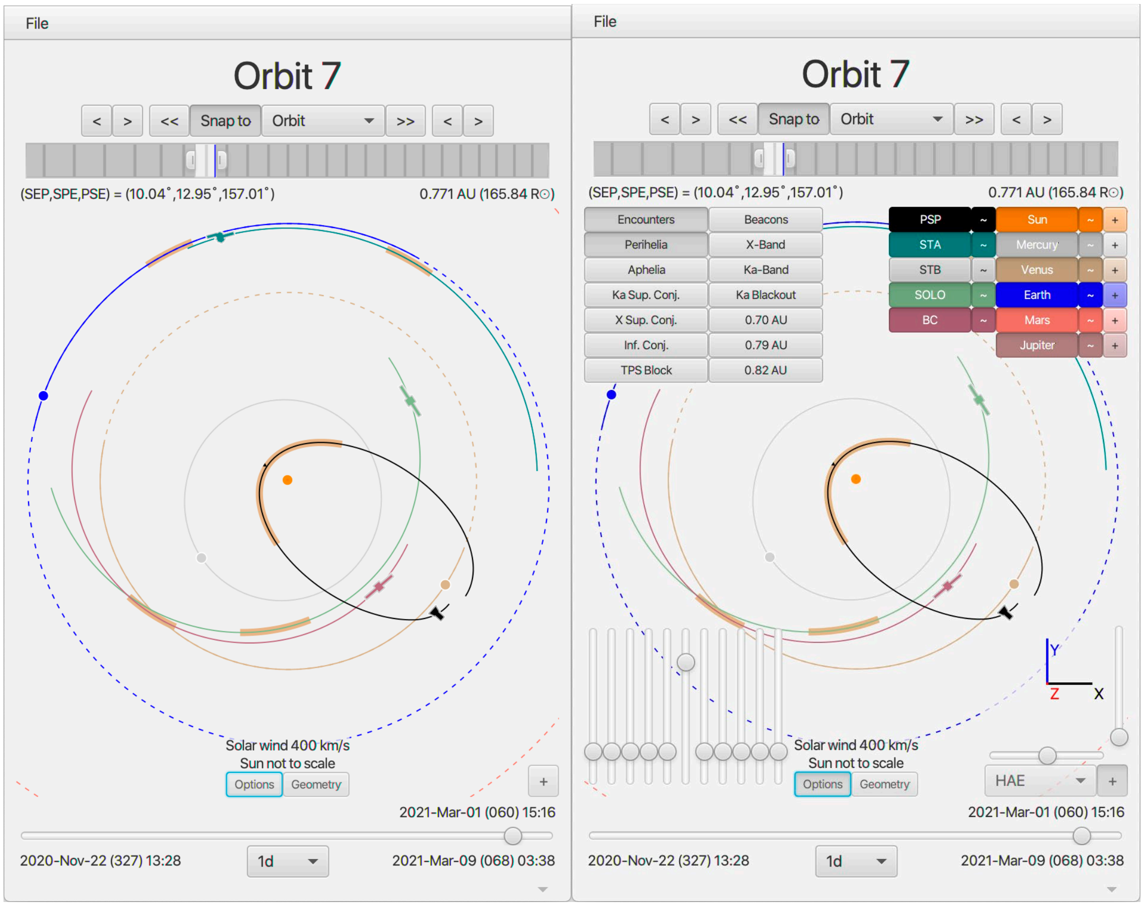

Figure 10.3 a: Left: default SPADER orbit plot view, showing the location of trajectories of various bodies for a single orbit; Right: the same window showing the heads-up display of selectable plot options and coordinate systems. Each button, when hovered with the mouse cursor, shows a pop-up tooltip describing the function of the button.

11.4 PASF Merger

The Orbit Planning Team will generate planning products containing downlinks, power on opportunities, command uplink opportunities and a Deep Space Network (DSN) default schedule for a specific orbit. The PASF merger utility in SPADER will be used by the science planning team to input those products and facilitate the selection of the instrument power on, command uplink, data transfer time periods and other activities that fit within the opportunities. PASF from each team will be produced and the SPLead and PPLs as a whole will resolve any conflicts and merge the files into one consolidated PASF.

The PASF Merger can create new PASF but also reads PASF created by Payload planning software. The PASF Merger tests for and enforces the proper activity time margins with each other, blackout periods and FIELDS and SWEAP high speed transfers. It detects activity format errors and attempts to correct them. It highlights the activities with errors and has tool tips that alert the user to the issue with the activity. Both graphic and table display of the activities are available in the tool.

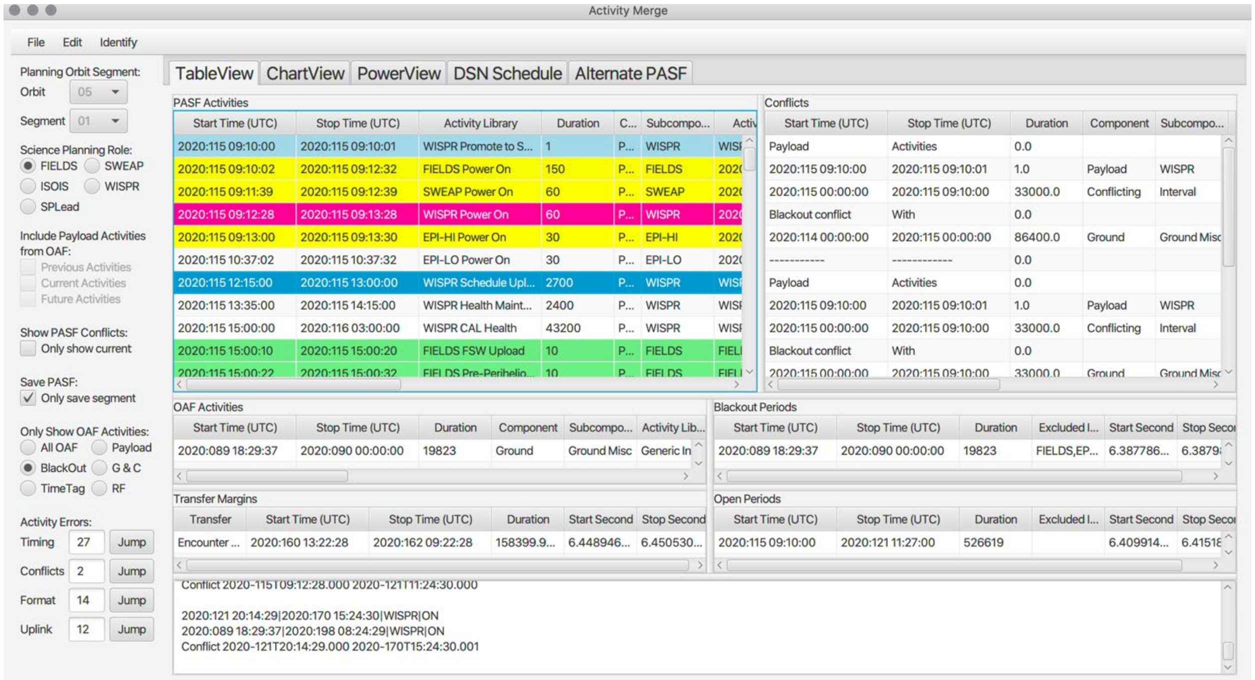

Figure 10.4 a: PASF Merger main menu. The PASF Activities table at the top left, shows the blackout and time tagged conflicted activities highlighted in blue, timing errors in yellow, format errors in pink and issues with activities requiring higher volume uploads in green. The conflict window on the top right, shows the conflicts with blackout periods. The OAF activities table in the middle left shows the OAF activities and can be filtered using the far left menu. The Blackout periods show when the payloads can not be on and the Open periods show when the payloads can be on. Both of these lists of periods can be written out to a file. The bottom window is the log window.

The PASF Merger has a staggering algorithm that re-arranges the payload power on and offs around the blackout periods in a pre-determined order to take maximum advantage of allowed payload on time.

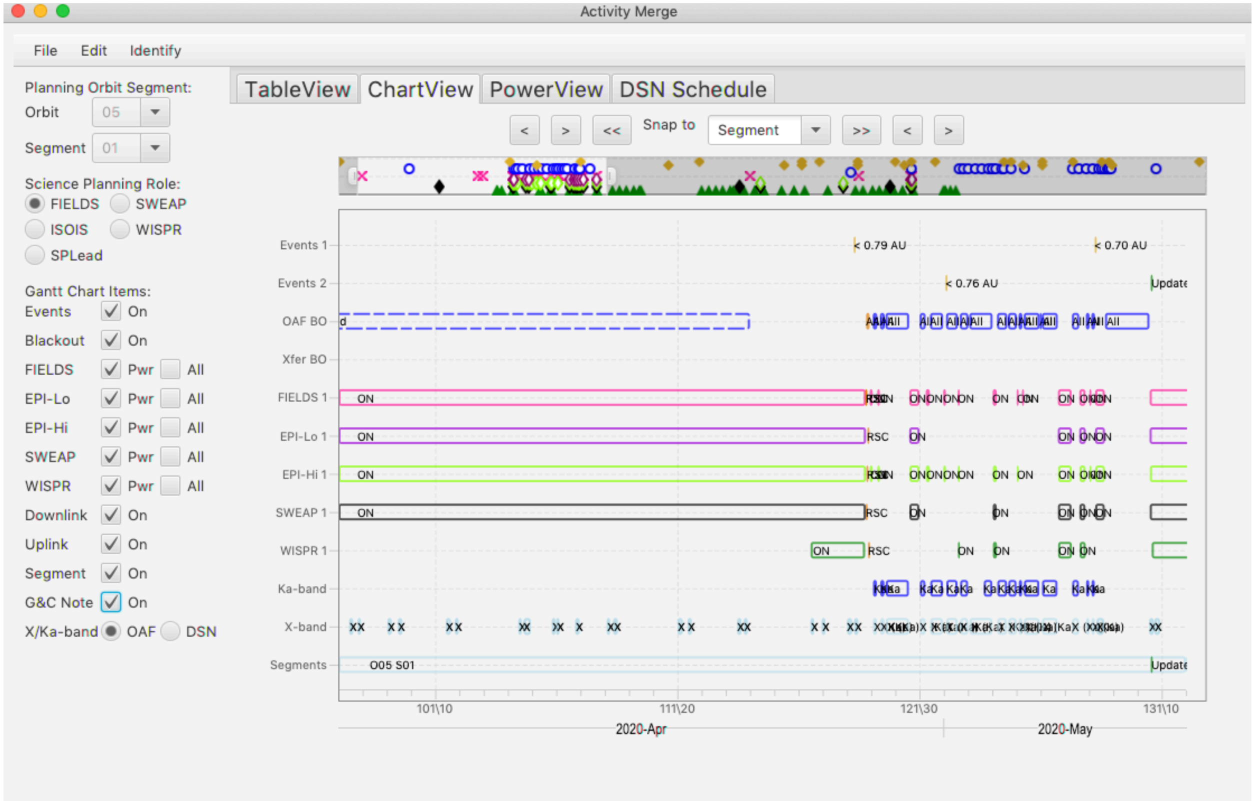

Figure 10.4 b: Gantt chart view of power on and off periods are shown.

The figure above shows the graphical view of activities which can be zoomed and navigated using the mouse buttons or the buttons at the top of the chart. All activities shown can be clicked on to bring up a popup window with a more detailed description. The orbital events are shown in the top two lines. The OAF BO and Xfer BO lines are OAF blackout period activities and transfer margin blackout periods. The FIELDS, EPI-Lo, EPI-Hi, SWEAP and WISPR lines show their power on periods. The Ka-band and X-band lines show the passes times. The bottom line shows the orbit segment periods.

A detailed difference output of two PASFs or two OAFs is available for users to facilitate Payload evaluation of the final merged PASF.

11.5 Activity Calendar

Due to the focused nature of the SPADER and PASF Merger tools on planning, a more general tool was desired to show payload and spacecraft activity in a calendar setting. The Activity Calendar displays the PASF activities and a limited set of the OAF activities as well as the orbital events. Updating the OAF and PASF file set is easily accomplished by downloading pre-made file sets.

The ActivityCalendar makes use of the CalendarFX open source calendar framework for JavaFX.

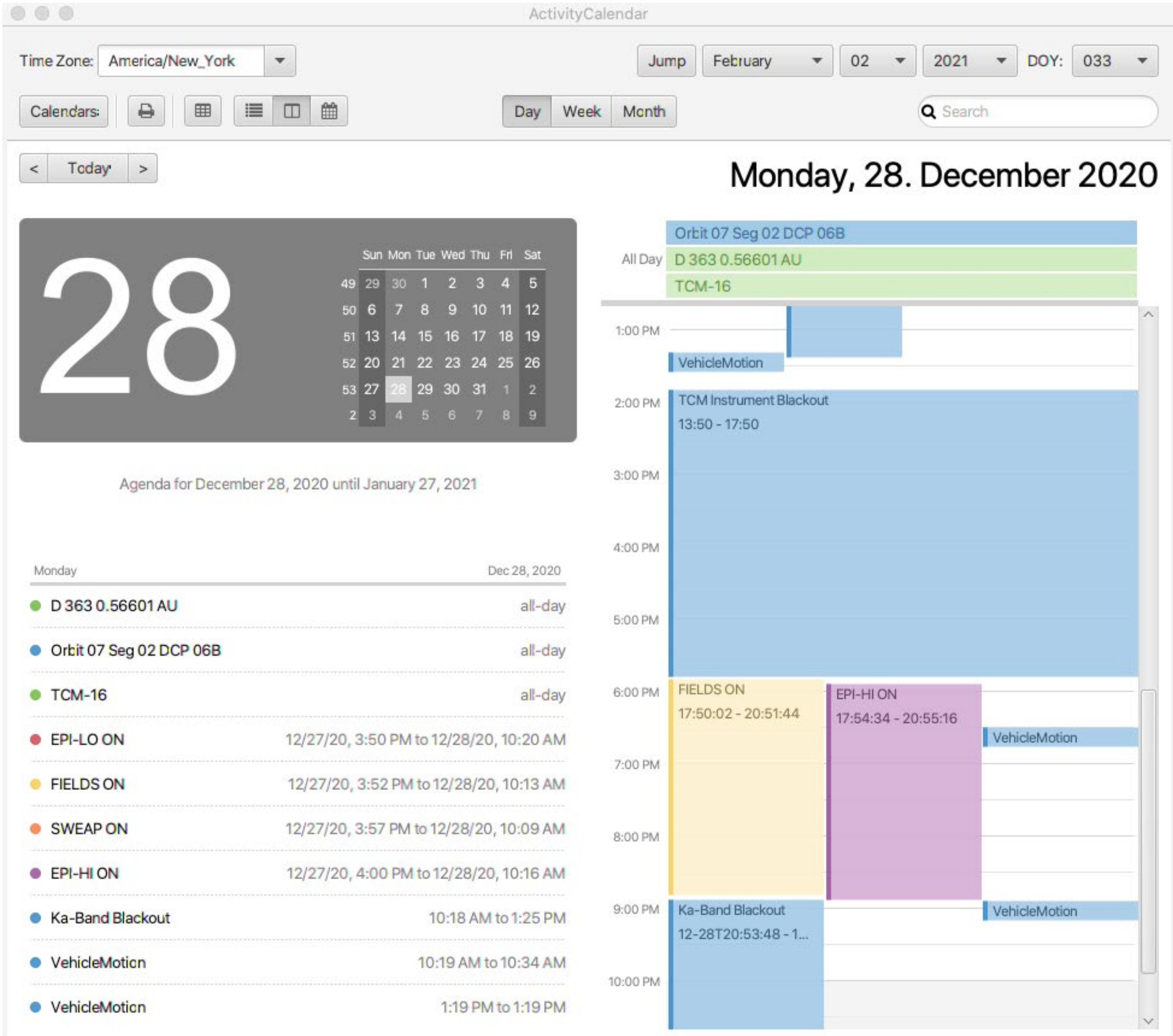

Figure 10.5 a: Day display for Activity Calendar. Week and Month displays are also available. Clicking on the activities will bring up a popup window with more detailed information. The top blue item in the All Day display are the Orbit, Orbit Segment and DCP numbers. The green item below that is the distance from the Sun in AU. The rest of the activities are from the Payloads or spacecraft.

12 APPENDIX: SPICE KERNELS

Kernel Type	Description	
MOPSSCLK	The SCLK is a daily produced kernel that supports time conversions between spacecraft clock and Barycentric Dynamical Time (TDB). The kernel is produced by the PSP mission.	
Long Term Predicted Ephemeris	This kernel contains a nominal PSP trajectory long term predicted ephemeris for the PSP spacecraft. The kernel is produced by the PSP mission.	
Reconstructed Ephemerides	This kernel contains the reconstructed ephemeris for the PSP spacecraft. The kernel is produced by the PSP mission.	
Leap Second	The kernel is used for Coordinated Universal Time (UTC) to TDB time conversions It contains a tabulation of all leap seconds that have occurred. It is a generic SPICE kernel, independent of flight project. The kernel is produced by NAIF and is only updated as needed.	
PSP Frame - Mission Frame	Mission Frame: The kernel contains definitions of and specification of relationships between reference frames. This frame kernel contains the current set of coordinate frame definitions for the Parker Solar Probe spacecraft, structures, and science instruments. The kernel is produced by the PSP mission.	
PSP Frame - Analysis Frame:	The kernel contains definitions of and specification of relationships between reference frames. This kernel contains SPICE frame definitions to support the Parker Solar Probe mission science data analysis needs. The kernel is produced by the PSP mission.	

PSP Frame - Instrument	Instrument field of view size, shape and orientation. This instrument kernel contains references to mounting alignment, operating modes, and timing as well as internal and field-of-view geometry for the Solar Probe Plus instruments. The kernel is produced by the PSP mission.	
Yearly Attitude History	This kernel contains the long-term attitude predict for the PSP spacecraft. The kernel is produced by the PSP mission.	
Attitude History	This kernel contains the daily attitude history for the PSP spacecraft. The kernel is produced by the PSP mission.	
Long Term Attitude Predict	This kernel contains the long term predicted attitude for the PSP spacecraft. The kernel is produced by the PSP mission.	
Short Term Attitude Predict	This kernel contains the short-term attitude predict for the PSP spacecraft. The kernel is produced by the PSP mission.	
Planetary Constant	The kernel is used to obtain celestial body orientation, size, shape and other constants. It is a generic SPICE kernel, independent of flight project. The kernel is produced by NAIF.	
Planetary Ephemerides	The kernel contains high precision ephemerides for solar-system bodies. It is a generic SPICE kernel, independent of flight project. The kernel is produced by JPL NAIF.	