**Project: Solar Orbiter SWA**

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# Introduction

## Purpose and Scope

This Data Product Definition Document (DPDD) describes the format and content of the Solar Wind Analyser (SWA) science data. It includes descriptions of the data products and associated metadata, including the data format, content, and any generation pipeline systems. These products will be stored and distributed from the Solar Orbiter Science Archive (SOAR) of the SOC.

The specifications described in this DPDD apply to all SWA science products submitted to ESA’s Solar Orbiter SOC for further archival and exploitation. This document only includes descriptions of science products delivered by the SWA science pipelines run by SWA. It does not address the Low Latency data which is described in [RD9].

## Reference Documents

The documents listed below form a part of this document, to the extent specified and described herein.

|  |  |  |
| --- | --- | --- |
| **Ref.** | **No** | **Title** |
| RD1 |  | CDF User’s Guide v3.5, available from <http://cdf.gsfc.nasa.gov> |
| RD2 | SOL-SGS-OTH-004-TPL\_DPDD | Solar Orbiter SWA Data Product Description Document template |
| RD3 | SOL-SGS-TN-0006 | SOC Engineering Guidelines for External Users |
| RD4 | ESA/SRE(2011)14 | Solar Orbiter definition study report (Red Book) |
| RD5 | SO-SWA-MSSL-RQ-010 | Solar Orbiter SWA Scientific Operations, Algorithms and Processes Requirements Document |
| RD6 | SOL-SGS-ICD-0004 | Solar Orbiter Interface Control Document for Low Latency Data CDF Files |
| RD7 | SOL-SGS-TN-0009 | Metadata Definition for Solar Orbiter Science |
| RD8 | SOL-SGS-PL-0009 | Solar Orbiter Archive Plan |
| RD9 | SO-SWA-MSSL-IF-005 | SWA Low Latency Data Product Description Document |
|  | SOL-SGS-ICD-002 | Data Producer to Archive ICD (DPAICD) |

## Acronyms, Abbreviations and Terms

| **Abbreviation** | **Meaning** |
| --- | --- |
| CCSDS | Consultative committee for space data systems |
| cdf | Common data format |
| CME | Coronal Mass Ejection |
| DPU | Data Processing Unit |
| EAS | Electron Analyser System |
| ESAC | European Space Astronomy Centre |
| FIP | First Ionisation Potential |
| FOV | Field of view |
| HIS | Heavy Ion System |
| LL | Low Latency |
| LLDPDD | Low Latency Data Product Definition Document |
| MHD | Magneto-Hydro-Dynamics |
| MOC | Mission Operations Centre |
| NM | Normal Mode |
| OBT | On board time |
| PAS | Proton Analyser System |
| PHA | Pulse Height Analysis |
| RPW | Radio Plasma Wave |
| S/C | Spacecraft |
| SCET | Space craft elapsed time |
| SEGU | Solar Orbiter engineering guidelines for external users |
| SOAR | Solar Orbiter Archive |
| SOC | Spacecraft Operations Centre |
| SSMM | Solid State Mass Memory |
| SWA | Solar Wind Analyser |
| TBC | To Be Confirmed |
| TBD | To Be Determined |
| TOF | Time of Flight |
| UTC | Universal coordinated time |
| VA | Virtual Appliance |
| VDF | Velocity Distribution Function |
| SOAR | Solar Orbiter Archive |
| OT | Operations Team at MSSL |
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# SWA Instrument Description

*High-level description of the instrument and instrument science objectives, with a reference to an external, publicly available instrument document (such as the instrument paper). The proposed structure for this section is indicated below (see sub-sections).*

## Science Objectives

*Describe the instrument science objectives.*

The overarching objective of SWA is to provide the comprehensive in situ measurements of the solar wind, which are critical if we are to establish the fundamental physical links between the Sun’s highly dynamic and inhomogeneous magnetised atmosphere and the solar wind in all its quiet and disturbed states.

This critical step requires comprehensive in-situ measurements of the various constituents of the solar wind plasma including high time resolution velocity distributions of solar wind ions and electrons and composition up to suprathermal energies – for example, the measurement of heavy ion charge states reflect coronal temperatures at their source. These measurements are vital if we are to discover the fundamental links between e.g. solar eruptions, shocks and the suprathermal ions that are the seed populations of hazardous solar particle events.

The SWA sensors will sample comparatively pristine solar wind plasma at the closest ever distances to the Sun, but also assess their radial evolution. This will provide key information on the evolution of the solar wind with distance from the Sun, providing a separation of those processes which are inherent in the solar wind itself from those which play a role in the formation of the wind near to the Sun. Furthermore, the SWA will for the first time measure the near-Sun solar wind at higher latitudes revealing the latitudinal dependence of these near-Sun phenomena as the spacecraft climbs out of the ecliptic. Solar Orbiter will thus extend our direct measurements of space plasmas into a new realm that will transform our view of the connections from the solar atmosphere into the solar wind, and help us project this understanding to other stellar environments. For further details see RD5.

SWA consists of four separate sensors, 2 Electron Analysers (EAS), a Proton/Alpha sensor (PAS) and a Heavy Ion Sensor (HIS). These sensors are connected to the central Data Processing Unit (DPU) that packets the sensor data and transmits them to the SSMM.

## SWA Operational Modes

*Description of the instrument modes, with references to the type of data products generated (defined in the following sections).*

The SWA sensors can each be operated in a variety of operational modes. These modes are sensor independent, meaning that each sensor can be a different mode from the other two sensors. The available modes are detailed below.

### Normal Mode

The default operating mode of all the SWA sensors is the ‘Normal Mode’. In this mode the full 3d data set from each sensor will be sent to the SSMM at the default cadence.

### Burst Mode

In ‘Burst Mode’, EAS, HIS and PAS data will be sent to the SSMM at higher cadences. This applies to various data types, not just Normal Mode. This is explained in detail below.

### Triggered Mode

This mode only applies to EAS. During Normal mode, the full, 1 second, 3d data is stored on a rolling buffer that can hold 5 minutes of data. Upon receipt of a ‘trigger’ from the RPW instrument. The entire, 5 minute buffer will be frozen and sent to the SSMM.

### Engineering Mode

All the SWA sensors have the ability to perform some calibration/engineering work. This data is intended to monitor the ‘health’ of the sensors in order to maintain the optimimum sensor configuration. In the event of sensor faults, the engineering mode data can be used in fault diagnosis.

## Calibration

### On-ground Calibration

*Description of the on-ground calibration performed on the instrument, and results. Include references to calibration performance reports.*

#### EAS On-ground Calibration

Geometric factor

#### PAS On-ground Calibration

The PAS on-ground calibration has been performed on the EQM, PFM and the FS using a large diameter, 300eV - 10 keV, He++beam.

The resulting calibration data file contains the following:

***A(ie, iel, iaz)*** The effective aperture in cm2 for each energy, ie = [0….95], each elevation, iel = [0…8], and each azimuth direction, iaz = [0….10] . Thus this is a (96, 9, 11) array. Note that these values already contain cosines since they are the results of the measurement. They also contain the detector efficiency as a function of the energy and individual CEM properties. These values may be updated in flight.

***ΔE(ie, iel, iaz) / E*** The unit-less energy resolution. It is also a (96, 9, 11) array. These values will also be updated in flight if the stepping voltages in the PAS sequencer are modified.

***Ω(ie, iel, iaz)*** The solid angle resolution in steradians (sr). It is also a (96, 9, 11). These values will be updated in flight if the stepping voltages in the PAS sequencer are modified.

***E(ie, iel, iaz)*** The energy per charge in electronvolts (eV). It is also a (96, 9, 11). These values will be updated in flight if the stepping voltages in the PAS sequencer are modified.

***Elev(ie, iel, iaz)*** The elevation angles, rad. It is also a (96, 9, 11). These values will be updated in flight if the stepping voltages in the PAS sequencer are modified.

***Az(iaz)*** Azimuth angles in radians (rad). This is an array of 11 values.

***ΔW(ie, iel, iaz)*** The integrating velocity volume in (cm3 sr / s3). This volume is defined by the measurement scheme rather than the calibration.

For the onboard moments calulation special tables will be included in the calibration data to include:

* Proton velocity value which depends on energy bin index *ie*



Here is the *E(ie, iel, iaz)* averaged over Elevation and Azimuth



* Elevation angle which depends on elevation bin number *iel*



* Sines and cosines of the main directions, calculated from Aziaz and Eleviel

Sin(Aziaz), Cos(Aziaz), Sin(Eleviel), Cos(Eleviel)

* The Count to partial density conversion factor :



Here, and is the “velocity”geometrical factor in cm2sr



#### HIS On-ground Calibration

### In-flight Calibration

*Description of the in-flight calibration, with references to existing document where applicable.*

#### EAS In-flight Calibration

The EAS in-flight calibration procedure varies the CEM HV and registers the CEM counts. The HV value that corresponds to the plateau of CEM counts is used as a nominal CEM HV until a next CEM gain adjust. This calibration is run by the DPU with a special engineering mode. The results of this are returned as a Low Latency product.

#### PAS In-flight Calibration

The PAS in-flight calibration consists of two parts:

1. CEM gain adjustment. This procedure varies the CEM HV and registers the CEM counts. The HV value that corresponds to the plateau of CEM counts is used as a nominal CEM HV until a next CEM gain adjust. To perform this calibration the DPU starts the “CEM Calibration” procedure. The results of this are returned as a Low Latency product.
2. HVPS levels calibration. This procedure provides a check of the HVPS optics voltages stability. To perform this calibration the DPU sets PAS to the “Ready\_To\_Science” state and then sends the “Engineering scheme” command. The results are packeted in the regular PAS HK packet.

#### HIS In-flight Calibration

# DATA GENERATION AND ANALYSIS PROCESS

The SWA science products are produced by the SWA Instrument Team. The data generation and analysis process is described in this section.

Science data received by the SOC from the SWA team are made available to end users through the Solar Orbiter archive following the policies described in the Archiving Plan [RD8].

The procedure for delivery of the Science data from the SWA Instrument Team to the SOC will be fully compliant with the IT-SOC Science Data Delivery ICD (TBW).

*(For Instrument Teams: please fill in each and all of the items below; in the exceptional case that your instrument is not producing one of the items, keep the item and explain why it is not being produced)*

## Scientific Measurement

*Top-level description of the data acquired by the instrument.*

### EAS

Each of the 2 EAS sensors measure electrons distributed over a spectrum of 64 energies, a 360o azimuthal range of 32 anodes and a 90o altitudinal range of 16 elevations, every second. Individually, each EAS will produce [64,32,16] arrays of data every second. Used together, the 2 EASs provide a full, 3d velocity space distribution covering the 4π space surrounding the EAS instrument every second.

The EAS instrument can operate in various modes or states that will return different subsets of the original 3d data. These are:

* **Normal Mode**. Every 100 seconds of the full 3d distribution from each EAS is sent to the SSMM. The data array dimensions will be [64,32,16] from each EAS;
* **Single Strahl**. Every 100 seconds (offset by 50 seconds from Normal Mode) a single energy bin slice of the full 3d distribution of each EAS is sent to the SSMM. The data array dimensions will be [1,32,16] from each EAS;
* **Burst Mode**. On command, the full 3d distribution from both EASs will be combined and reduced to a single altitudinal bin and transmitted every second to the DPU. The data array dimensions will be [64,32,2] from both EAS combined.
* **Triggered Mode**. Autonomously commanded by the DPU on receipt of a trigger flag, 5 minutes of buffered, 1 second, full 3d velocity distribution from each EAS, will be transmitted to the SSMM by the DPU. The data array dimensions will be [64,32,16] from each EAS.

The relationship between the EAS modes and states and the DPU is illustrated in Figure 3.1 below.



Figure .: SWA EAS data flow within the sensors and DPU

The DPU will use the full 3d velocity space distributions from both EASs and create a set of on-board electron moments every 4 seconds that are transmitted to the SSMM. The scheme for generation of the onboard moments from EAS by the DPU is shown in Figure 3.2 below.



Figure .: EAS Moment generation scheme

Together with the Housekeeping from each EAS, there are also various engineering modes that allow instrument health monitoring and fault diagnosis to be performed on a semi-regular basis (~1 per week, for a limited duration) in order to ensure that the sensor is maintained in optimum configuration.

### PAS

The PAS sensor measures protons and alpha particles distributed over a spectrum of 96 energies, a 66o azimuthal range of 11 anodes and a 45o altitudinal range of 9 elevations, every second. PAS can produce [96,11,9] arrays of data every second. However the default setting is to reduce this number to

PAS can operate in various modes and states that will return different subsets of the original 3d data. These modes are:

* **Normal Mode**. Every 4 seconds the full 3d distribution from PAS is sent to the SSMM. The data array dimensions will be [48,7,5];
* **Snap shot**. Every 300 seconds, a subset of the full 3d is collected at a faster rate of 4 times per second. The data array dimensions will be [48,7,3];
* **Burst Mode**. On command, PAS will send out data at 4 times per second, for 300 seconds. The data array dimensions will be [48,7,3].

The relationship between the PAS modes and states and the DPU is illustrated in Figure 3.3 below.



Figure . SWA PAS data flow within the sensors and DPU

From the normal 3D distributions, SWA DPU will calculate a set of proton/alpha moments every four seconds. The PAS moment product will consist of a single density value, a 3-element velocity vector, and 6 terms from a 9-element pressure tensor. Twenty-five PAS moment products will be packeted into one ccsds packet with the appropriate headers and sent to the SSMM LL01 packet store.

In order to ensure that the sensor is maintained in optimum configuration, the raw PAS data can also contain engineering mode data that allows instrument health monitoring of temperatures and voltages, and fault diagnosis to be performed on a semi-regular basis (~1 per week, for a limited duration). Some of this data will be compressed, packeted with header and sent to the SSMM LL01 packet store. The engineering mode data in the Low Latency packets will be used by the PAS team only. There will be no requirement of the SOC team to process this data.

### HIS

The HIS sensor measures heavier ions distributed over a spectrum of energies and over a range of azimuths and elevations to provide a partial phase space distribution covering the ram direction plasma. HIS also measures time of flight (TOF) of these particles in order to determine species. Each heavy ion entering HIS is deemed and event and the rates of events over different ranges (energy, elevation, TOF) are recorded. HIS will return several types of data packet that are described in the following sections. The rates of these packets will depend on the operating Mode.

* **Normal Mode**. In normal mode, HIS returns packets every 300 seconds with an option to increase to 30 seconds.
* **Burst Mode**. In normal mode, HIS returns packets every 4 seconds.

Together with the Housekeeping from HIS, there is also an engineering mode that allows instrument health monitoring and fault diagnosis to ensure that the sensor is maintained in optimum configuration.

### SWA L-1 Data

The data described above are returned in individual CCSDS packets. Once on the ground, these packets are decommutated and uncompressed to form the L-1 raw data packets. These files are still in ccsds format and are saved in binary format.

The MSSL Operations team is responsible for retrieving the raw CCSDS data and creating the L-1 binary packets. The process used to create these data files is a simple C code that searches on the data type, subtype and SID. If the data is compressed it is passed through an uncompressor before being grouped into appropriate files. Table 3.1 shows how the data files are grouped together.

|  |  |
| --- | --- |
| **SWA L-1 Data filename** | **Possible Contents**  **Type, SubType, SID, SCOS\_ID** |
| solo\_L-1\_swa-dpu-REP\_[StartTime-EndTime]\_V01.bin | 200, 248, 0, YIA58970  200, 249, 0, YIA58166  200, 250, 0, YIA58900  200, 251, 0, YIA58901  200, 252, 0, YIA58902  200, 253, 0, YIA58903  201, 200, 0, YIA58904  202, 200, 0, YIA58905  203, 200, 0, YIA58906 |
| solo\_L-1\_swa-dpu-HK\_[StartTime-EndTime]\_V01.bin | 3, 25, 11, YIA58200  3, 25, 14, YIA58211  3, 25, 15, YIA58998  3, 25, 20, YIA58216  3, 26, 4, YIA58204  3, 26, 5, YIA58205  3, 26, 6, YIA58206  3, 26, 7, YIA58207  3, 26, 8, YIA58208  3, 26, 9, YIA58209  3, 26, 10, YIA58210  3, 26, 12, YIA58214  3, 26, 13, YIA58215 |
| solo\_L-1\_swa-eas1-NM\_[StartTime-EndTime]\_V01.bin | 21, 3, 0, YIA58703  21, 6, 1, YIA58704  21, 3, 2, YIA58708 (Uncompressed)  21, 6, 3, YIA58709 (Uncompressed) |
| solo\_L-1\_swa-eas1-SS\_[StartTime-EndTime]\_V01.bin | 21, 6, 8, YIA58712  21, 6, 9, YIA58713 (Uncompressed) |
| solo\_L-1\_swa-eas1-TM\_[StartTime-EndTime]\_V01.bin | 21, 3, 5, YIA58716 (Uncompressed)  21, 3, 6, YIA58720 (Uncompressed)  21, 6, 7, YIA58724 (Uncompressed)  21, 3, 10, YIA58717  21, 3, 11, YIA58721  21, 6, 12, YIA58725 |
| solo\_L-1\_swa-eas1-ENG\_[StartTime-EndTime]\_V01.bin | 21, 3, 13, YIA58917  21, 3, 14, YIA58927 (Uncompressed)  21, 3, 14, YIA58946 (Uncompressed)  21, 3, 15, YIA58929 (Uncompressed)  21, 3, 15, YIA58948 (Uncompressed)  21, 6, 16, YIA58931 (Uncompressed)  21, 6, 16, YIA58950 (Uncompressed)  21, 3, 17, YIA58920  21, 3, 17, YIA58940  21, 3, 18, YIA58921  21, 3, 18, YIA58942  21, 6, 19, YIA58922  21 6, 19, YIA58944 |
| solo\_L-1\_swa-eas1-HK\_[StartTime-EndTime]\_V01.bin | 3, 25, 1, YIA58201 |
| solo\_L-1\_swa-eas2-NM\_[StartTime-EndTime]\_V01.bin | 21, 3, 30, YIA58701  21, 6, 31, YIA58702  21, 3, 32, YIA58706 (Uncompressed)  21, 6, 33, YIA58707 (Uncompressed) |
| solo\_L-1\_swa-eas2-SS\_[StartTime-EndTime]\_V01.bin | 21, 6, 38, YIA58710  21, 6, 39, YIA58711 |
| solo\_L-1\_swa-eas2-TM\_[StartTime-EndTime]\_V01.bin | 21, 3, 35, YIA58714 (Uncompressed)  21, 3, 36, YIA58718 (Uncompressed)  21, 6, 37, YIA58722 (Uncompressed)  21, 3, 40, YIA58715  21, 3, 41, YIA58719  21, 6, 42, YIA58723 |
| solo\_L-1\_swa-eas2-ENG\_[StartTime-EndTime]\_V01.bin | 21, 3, 43, YIA58918  21, 3, 44, YIA58947 (Uncompressed)  21, 3, 44, YIA58926 (Uncompressed)  21, 3, 45, YIA58928 (Uncompressed)  21, 3, 45, YIA58949 (Uncompressed)  21, 6, 46, YIA58930 (Uncompressed)  21, 6, 46, YIA58951 (Uncompressed)  21, 3, 47, YIA58923  21, 3, 47, YIA58941  21, 3, 48, YIA58924  21, 3, 48, YIA58943  21, 6, 49, YIA58925  21 6, 49, YIA58945 |
| solo\_L-1\_swa-eas2-HK\_[StartTime-EndTime]\_V01.bin | 3, 25, 2, YIA58202 |
| solo\_L-1\_swa-eas-MOM\_[StartTime-EndTime]\_V01.bin | 21, 3, 20, YIA58727 |
| solo\_L-1\_swa-eas-BM\_[StartTime-EndTime]\_V01.bin | 21, 6, 4, YIA58726 (Uncompressed)  21, 6, 4, YIA58889 (Uncompressed) |
| solo\_L-1\_swa-pas-NM\_[StartTime-EndTime]\_V01.bin | 21, 3, 192, YIA58700  21, 6, 193, YIA58705  21, 3, 194, YIA58977 (Uncompressed)  21, 6, 195, YIA58978 (Uncompressed) |
| solo\_L-1\_swa-pas-TM\_[StartTime-EndTime]\_V01.bin | 21, 3, 196, YIA58979 (Uncompressed)  21, 3, 197, YIA58986 (Uncompressed)  21, 6, 198, YIA58987 (Uncompressed)  21, 3, 199, YIA58980  21, 3, 200, YIA58988  21, 3, 201, YIA58989 |
| solo\_L-1\_swa-pas-SNAP\_[StartTime-EndTime]\_V01.bin | 21, 3, 202, YIA58981 (Uncompressed)  21, 3, 203, YIA58990 (Uncompressed)  21, 6, 204, YIA58991 (Uncompressed)  21, 3, 205, YIA58982  21, 3, 206, YIA58992  21, 6, 207, YIA58993 |
| solo\_L-1\_swa-pas-BM\_[StartTime-EndTime]\_V01.bin | 21, 3, 208, YIA58883 (Uncompressed)  21, 3, 208, YIA58983 (Uncompressed)  21, 3, 209, YIA58884 (Uncompressed)  21, 3, 209, YIA58994 (Uncompressed)  21, 6, 210, YIA58885 (Uncompressed)  21, 6, 210, YIA58995 (Uncompressed)  21, 3, 211, YIA58886  21, 3, 211, YIA58984  21, 3, 212, YIA58887  21, 3, 212, YIA58996  21, 6, 213, YIA58888  21, 6, 213, YIA58997 |
| solo\_L-1\_swa-pas-CAL\_[StartTime-EndTime]\_V01.bin | 21, 6, 214, YIA58985 |
| solo\_L-1\_swa-pas-MOM\_[StartTime-EndTime]\_V01.bin | 21, 6, 215, YIA58729 |
| solo\_L-1\_swa-pas-HK\_[StartTime-EndTime]\_V01.bin | 3, 25, 3, YIA58203 |
| solo\_L-1\_swa-his-TEST\_[StartTime-EndTime]\_V01.bin | 21, 3, 191, YIA58968 (normal)  21, 3, 191, YIA58969 (burst) |
| solo\_L-1\_swa-his-CONFIG\_[StartTime-EndTime]\_V01.bin | 21, 3, 128, YIA58800 (normal)  21, 3, 128, YIA58801 (burst) |
| solo\_L-1\_swa-his-PHA\_[StartTime-EndTime]\_V01.bin | 21, 6, 128, YIA58808 (normal)  21, 6, 128, YIA58809 (burst) |
| solo\_L-1\_swa-his-MATRIX\_[StartTime-EndTime]\_V01.bin | 21, 6, 129, YIA58802 (normal)  21, 6, 129, YIA58803 (burst) |
| solo\_L-1\_swa-his-VDF\_[StartTime-EndTime]\_V01.bin | 21, 6, 130, YIA58806 (normal)  21, 6, 130, YIA58807 (burst) |
| solo\_L-1\_swa-his-PRIO\_[StartTime-EndTime]\_V01.bin | 21, 6, 131, YIA58804 (normal)  21, 6, 131, YIA58805 (burst) |
| solo\_L-1\_swa-his-LL\_[StartTime-EndTime]\_V01.bin | 21, 6, 132, YIA58810 (normal)  21, 6, 133, YIA58811 (burst)  21, 6, 134, YIA58812 (burst) |
| solo\_L-1\_swa-his-HK\_[StartTime-EndTime]\_V01.bin | 3, 25, 100, YIA58213  3, 25, 101, YIA58212  3, 25, 102, YIA58184 |

Table . Level L-1 grouping of raw packets

The MSSL Operations team is also responsible for generating the L0 decompressed SWA .cdf packets as described below.

## Data Flow Overview

*This section will include a top-level description of the data processing workflow.*

*[Include Block Diagram showing the data sources and the processing steps]*



Figure .. SWA data flow schematic

The SWA data processing flows from the MOC data delivery service through a series of processing pipelines and back out to the SOC archive and other archives as illustrated in Figure 3.4

In Figure 3.4 there are six distinct pipelines, shaded green:

1. SWA L-1, L0 Pipeline: This is located at MSSL. It retrieves the data from the EDDS and performs a first unpack, decommutating the ccsds packets into relevant files for HIS, PAS and EAS. If a packet has been compressed on-board, it will be uncompressed in this pipeline. The decommutated and uncompressed ccsds packet files are grouped together in 24 hour files and stored at MSSL. They are available to the wider SWA team. The pipeline then proceeds to produce the L0 data product from the L-1 data. L0 data is in .cdf format, it is in 24 hour files, is stored at MSSL and is available to the wider team.
2. SWA Low Latency Pipeline: This pipeline is identical to the SWA pipeline hosted as a virtual machine at SOC. This pipeline will take SOC raw data and produce L0 .cdf files. These will be stored in the MSSL L0 data store.
3. PAS/HIS/EAS L1, L2, L3 Pipeline: These pipelines are hosted at the relevant institute. The pipeline will be fed the L-1 data and produce the L1, L2 and L3 data products. These pipelines may also use external data. The higher level products will then be piped back to MSSL where they will be archived.
4. SWA Archive Pipeline: This pipeline simply takes the higher level data products and sends the to the relevant external archives.

## Data Generation

The following sections describe the process used to produce the data products described in section 4.

### SWA L0 Data

The SWA L0 data is the uncalibrated, uncompressed L-1 data in CDF format. The individual sensor teams are responsible for generating SWA L0 data from the L-1 packets. These CDF files will have the ccsds header data and the ccsds science data combined.

#### SWA EAS L0 Data

MSSL is responsible for generating the SWA EAS L0 data form the L-1 source. The EAS L0 data products are, for each EAS, as follows:

* Normal Mode Spectra in counts, one set for each EAS sensor. The angular bin directions are in the EAS sensor reference frames.
* Burst Mode spectra in counts, from one sensor viewing the magnetic field direction. The angular bin directions are in the relevant EAS sensor frame.
* Partial moments calculated on board (6 sets per EAS sensor) in physical units. The frame references are the EAS sensor reference frames.
* Engineering mode data.

#### SWA PAS L0 Data

IRAP is responsible for generating the SWA PAS L0 data form the L-1 source. The PAS L0 data products are as follows:

* Normal Mode Spectra in counts. The angular bin directions are in the PAS frame.
* Normal Mode Snapshot Spectra. The angular bin directions are in the PAS frame.
* Burst Mode spectra. The angular bin directions are in the PAS frame.
* Onboard moments in physical units. In the PAS frame of reference.
* Engineering and Calibration data.

All Data products are made as CDF files according to “SOL-SGS-TN-0009 Metadata Definition for Solar Orbiter Science Data”. As well as being stored in the SWA Master Repository at MSSL with the L-1 data. These files will also be stored in CDPP data archive. These files will also be converted to NetCDF format to fit the AMDA tool spec.

#### SWA HIS L0 Data

UMich is responsible for generating the L0 HIS data form the L-1 source. This data will be in CDF format. SWA HIS L0 data products are as follows:

* PHA words. Individual ion event data, containing full information on incident angles (elevation and azimuth), E/q, TOF and SSD energy. The resolution of this data product can be 30s or 300s. In Burst mode the resolution can be 4s but this can only be run on average 1% of the time due to telemetry constraints.
* Priority Rates. Counts of PHA events within a priority range. Priority ranges are defined by large Energy-TOF boxes, defined separately for each E/q. The resolution of this data product can be 30s or 300s. In Burst mode the resolution can be 4s but this can only be run on average 1% of the time due to telemetry constraints.
* Sensor rates. Counts of unclassified PHA events as a function of E/q, integrated over incident angles, TOF and Energy. Includes full counts of events subject to decimation. The event will include, Start, Stop, SSD, Double coincidence and Triple coincidence. The resolution of this data product can be 30s or 300s. In Burst mode the resolution can be 4s but this can only be run on average 1% of the time due to telemetry constraints.
* Rate-based velocity distribution functions. Rates subdivided by incident angles and E/q, a selection of ions to include He2+, C5+, O6+, and Fe10+. Additional ions and charge states may be produced according to science needs and as counting statistics allow. The resolution of this data product can be 30s or 300s. In Burst mode the resolution can be 4s but this can only be run on average 1% of the time due to telemetry constraints.
* Matrix rates. Counts of PHA events within a specified Energy-TOF range, classified and counted onboard. Summed over incident angles. Classification transforms E/q, TOF and residual energy into the two dimensions of Energy and TOF. Ions included are He2+, O6-7+, C4-6+, and Fe10+. Additional ions and charge states may be produced according to science needs and as counting statistics allow. The resolution of this data product can be 30s or 300s. In Burst mode the resolution can be 4s but this can only be run on average 1% of the time due to telemetry constraints.
* Low-latency Data. Two rate spectra plus two rate ratios packaged into a single packet. These packets are handled separately from other science data and are downlinked at high-priority, at essentially the same intervals as housekeeping data

All Data products are made as CDF files according to “SOL-SGS-TN-0009 Metadata Definition for Solar Orbiter Science Data”. As well as being stored at MSSL, these files shall be stored in \*\*NASA\*\* data archive.

### SWA L1 Data

The SWA L1 data product contains ‘Engineered Data’. This is any SWA L0 data that has been ‘engineered’. An example of this could be any data that has had its time stamp changed, or any L0 data that has had some instrumental calibration performed on it. The SWA L1 data will be generated by the SWA sensor teams and returned to the MSSL Operations team who is responsible for storing the SWA L1 data.

The SWA L1 data products are TBD.

Any SWA L1 data products described above will be stored, with appropriate metadata, within CDF files according to “SOL-SGS-TN-0009 Metadata Definition for Solar Orbiter Science Data”.

Illustrations of the higher level data product flow for EAS and PAS are shown in Figure 3.5 and Figure 3.6 below.



Figure . Illustration of the SWA-EAS higher level data flow



Figure . Illustration of the SWA-PAS higher level data flow

### SWA L2 Data

#### SWA EAS L2 Data

The MSSL Operations team is responsible for generating SWA EAS L2 data. The generation of the full set of SWA EASA L2 data products requires a number of auxiliary files including:

* L0 data products;
* EAS Ground Calibration files;
* EAS Flight Calibration files (Obtained from L0 engineering/cal data);
* Spacecraft orbit and attitude information files (e.g. SPICE kernels);
* Spacecraft potential data from the RPW instrument;
* Magnetic field direction associated with each burst mode sample from the MAG instrument.

The set of SWA EAS L2 data products includes the following:

* Normal mode full onboard moment set for electrons in physical units and relevant heliospheric frame (produced by appropriately combining partial moments data with reference to the spacecraft potential from RPW) - at 4 second time resolution;
* Normal mode combined 3D electron distributions expressed as a distribution function with physical units and in a relevant heliospheric frame. These are produced by appropriately combining spectra from the 2 sensors. Time resolution 100 seconds;
* Normal mode combined 3D electron distributions expressed as a differential energy (number) flux and in a relevant heliospheric frame. These are again produced by appropriately combining spectra from the 2 sensors. Time resolution 100 seconds;
* Trigger event combined 3D electron distributions expressed as a distribution function with physical units and in a relevant heliospheric frame. These are produced by appropriately combining spectra from the 2 sensors. Time resolution 1 second for a 5 minute period;
* Trigger event combined 3D electron distributions expressed as a differential energy (number) flux and in a relevant heliospheric frame. These are again produced by appropriately combining spectra from the 2 sensors. Time resolution 1 second for a 5 minute period;
* Burst mode combined 2D electron pitch-angle distributions expressed with physical units and in a frame defined by the magnetic field direction. These are produced by appropriately rebinning the data from 2 elevation scans with respect to the field direction. Time resolution 0.125 seconds for a limited (few minute) period;
* Burst mode combined 2D electron pitch-angle distributions expressed as a differential energy (number) flux and in a frame defined by the magnetic field direction. These are produced by appropriately rebinning the data from 2 elevation scans with respect to the field direction. Time resolution 0.125 seconds for a limited (few minute) period;
* Normal mode combined single energy angle-angle electron distributions expressed as a distribution function with physical units and in a relevant heliospheric frame. These are produced by appropriately combining spectra from the 2 sensors. Time resolution 100 seconds;
* Normal mode combined single energy angle-angle electron distributions expressed as a differential energy (number) flux and in a relevant heliospheric frame. These are produced by appropriately combining spectra from the 2 sensors. Time resolution 100 seconds;
* Ground-calculated electron moments generated from the normal mode combined 3D electron distributions, in physical units and relevant heliospheric frame (produced with reference to the spacecraft potential from RPW) - at 100 second time resolution;
* Ground-calculated electron moments generated from the trigger events combined 3D electron distributions, in physical units and relevant heliospheric frame (produced with reference to the spacecraft potential from RPW) - at 1 second time resolution over a 5 minute period;

Again, all L2 data products described above will be stored, with appropriate metadata, within CDF files according to “SOL-SGS-TN-0009 Metadata Definition for Solar Orbiter Science Data”. These files will be stored in the SWA Master Repository at MSSL, along with the L2 data from the other SWA sensors and the auxiliary data generated from the mission. A number (all, subject to discussion?) of these data files will be submitted to the official ESA Solar Orbiter Archive, to the NASA NSSDC archive and the CDPP data archive in France following PI review and approval.

These files may be converted by the MSSL team to appropriate format (e.g. NetCDF format to fit the AMDA tool spec.) as requested by the archives.

#### SWA PAS L2 Data

IRAP is responsible for generating the SWA PAS L2 data. To produce the SWA PAS L2 data, the following auxiliary files are required:

* L-1 or L0 data products
* PAS Ground Calibration files
* PAS Flight Calibration files (Obtained from L0)
* Spacecraft orbit and attitude information files (e.g. SPICE kernels)

IRAP will produce the following SWA PAS L2 files:

* Normal mode 3D ion distributions expressed as a differential flux in the Solar-Ecliptic Frame
* Normal mode 3D ion distributions expressed as a distribution function in the Solar-Ecliptic Frame
* Snapshot and Burst fast 3D ion distributions expressed as a differential flux in the Solar-Ecliptic Frame
* Snapshot and Burst fast 3D ion distributions expressed as a distribution function in the Solar-Ecliptic Frame
* Ground calculated H+ moments in the Solar-Ecliptic Frame
* Ground calculated He++ moments in the Solar-Ecliptic Frame

All Data products are made as CDF files according to “SOL-SGS-TN-0009 Metadata Definition for Solar Orbiter Science Data”. As well as being stored at MSSL, the PAS L2 files shall be stored in CDPP data archive after a PI review and approvement. These files shall be converted also to NetCDF format to fit the AMDA tool spec.

All PAS L2 data can be delivered to ESAC archive after a PI review and approvement.

#### SWA HIS L2 Data

UMich is responsible for generating the SWA HIS L2 data. To produce the SWA HIS L2 data, the following auxiliary files are required:

* L-1 or L0 data products
* HIS Ground Calibration files
* HIS Flight Calibration files (Obtained from L-1 or L0)
* Spacecraft orbit and attitude information files (e.g. SPICE kernels)

Umich will provide the following SWA HIS L2 data products. Further details of these products is given below in Table 3.2.

* Elemental Abundances: Sum of all ion densities for a particular element as a ratio to those of oxygen.
* Ionic Charge States: Density ratios for specified ion pairs or average charge state, computed as density-weighted average
* Charge State Distributions: Normalized distribution of all charge states analyzed for specified element.
* Kinetic Properties: Moments of velocity distribution functions for specified ions. Includes density, bulk velocity and temperature.
* Velocity Distributions: Phase space density in instrument frame, binned according to speed, incident angles (elevation and azimuth).

|  |  |
| --- | --- |
| **Data Product** | **Time Resolutions**1 |
| **Elemental Abundances** |  |
| Fe/O | 30s, 300s, 4s2 |
| C/O | 30s, 300s, 4s2 |
| He/O | 30s, 300s, 4s2 |
| Mg/O | 30s, 300s |
| Si/O | 30s, 300s |
| Ne/O | 30s, 300s |
| S/O | >300s3 |
| N/O | >300s |
| **Ionic charge states** |  |
| O7+/O6+ | 30s, 300s, 4s2 |
| C6+/C4+ | 30s, 300s, 4s2 |
| C5+/C4+ | 30s, 300s, 4s2 |
| <QO> | 30s, 300s, 4s2 |
| <QC> | 30s, 300s, 4s2 |
| <QFe> | 30s, 300s, 4s2 |
| **Ionic Charge State Distributions** | |
| Qi(O), i =5,..8 | 30s, 300s |
| Qi(C), i=4,..,6 | 30s, 300s |
| Qi(Fe), i=6,…,20 | 30s, 300s |
| Qi(Si), i=6,…,12 | 30s, 300s |
| Qi(Ne), i=8,…,10 | 30s, 300s |
| Qi(Mg), i=5,…,12 | 30s, 300s |
|  |  |
| Qi(N), i=5,6 | 30s, 300s3 |
| Qi(S), i=6,…,14 | 30s, 300s3 |
| **Kinetic properties (n, vbulk, T)** | |
| He2+ | 30s, 300s, 4s2 |
| C5+ | 30s, 300s, 4s2 |
| O6+ | 30s, 300s, 4s2 |
| Fe10+ | 30s, 300s, 4s2 |
| **Velocity Distributions**4 |  |
| He2+ | 30s, 300s, 4s2 |
| C | 30s, 300s, 4s2 |
| O6+ | 30s, 300s, 4s2 |
| Fe10+ | 30s, 300s, 4s2 |

Table 3.2 SWA-HIS Level 2 derived data products in physical units

Note 1: These are the possible time resolutions. For some periods in the solar wind, the highest time-resolution will not provide data with sufficient statistical accuracy. The best, most scientifically useful averaging intervals will be determined based on the counting accuracy achievable.

Note 2: Data at this resolution corresponds to HIS Burst mode, which can only be run on average 1% of the time due to telemetry constraints.

Note 3: These elements are more difficult to resolve. Appropriate time resolutions will be determined in flight.

Note 4: Additional charge states may be produced during periods of high counting statistics.

### SWA L3 Data

The SWA team may generate further L3 data products as required. At present these are still TBD. Possible data products that can be further generated from the L1 or L2 and auxiliary data files might include:

* EAS Pitch Angle Distributions generated from the Normal Mode 3D distributions with reference to the magnetic field direction (time resolution 100secs);
* EAS Pitch Angle Distributions generated from the Trigger event 3D distributions with reference to the magnetic field direction (time resolution 1 second for a 5 minute period;
* EAS Moments over reduced energy ranges (e.g. by appropriately combining partial moment data to provide a quantification of the plasma characteristics in only the strahl energy range – time resolution 4 seconds – or by moment integration performed on L2 normal mode 3D distributions over a limited energy range – time resolution 100 seconds);
* PAS All sky maps

MSSL will define a set of appropriate physical reference frames in which to produce and store the data (or produce one in which manipulations to other frames (e.g. using SPICE kernels) is straightforward for the community.

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

TBD

*There are two coordinate reference systems that SWA can use to represent L2 data. Both are used for STERO mission. SWA team shall define which coordinate system we will use for L2/L3 data products:*

*Solar-Orbit (SO), X is the line connection Solar Orbiter and the Sun center, Y is in the plane of the S/C orbit towards the SC velocity vector.*

*Solar-Equator-Spacecraft (SES) that equals to STEREO* ***HGRTN/RTN :*** *X axis points from Sun center to the spacecraft, and the Y axis is the cross product of the solar rotational axis and X, and lies in the solar equatorial plane (towards the West limb).*

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

## Validation

The following sections describe the process by which the data products are validated.

### Instrument Team Validation

Upon ingestion of the raw CCSDS telemetry at MSSL, initial testing will be performed on the raw data. This will include:

* SID counter tests to ensure all packets are present.

### SOC Validation

The SOC will check the data types that the SWA team intends to archive. The SOC might also perform spot checks on contents of the files. The exact procedure in which this routine check will take place is still TBD.

# Data Product Descriptions

SWA data products are formatted in accordance with the rules outlined in [RD7]. This section provides details on the filenames, formats and metadata for each of the products included in the SWA science data.

**Level Source Data Type Format and Metadata content**

|  |  |  |  |
| --- | --- | --- | --- |
| **Level** | **Source** | **Data Type** | **Format and Metadata content** |
| L-1 | IT | "Raw" data, unpacked and uncompressed data | Decommutated and uncompressed CCSDS metadata reflect the information that was available in the TM packets only. |
| L0 | IT | "Raw" data, unpacked and uncompressed data | CDF, metadata reflect the information that was available in the TM packets only. |
| L1 | IT | "Engineering" data, uncalibrated | CDF, metadata follows Solar Orbiter standard for L1 |
| L2 | IT | "Calibrated" data, science quality | CDF, metadata follows Solar Orbiter standard for L2 (see Section Solar Orbiter Metadata Standard): full attitude information in WCS coordinate frame and time in UTC. |
| *L3* | *IT* | *Higher-level data* | *Data format as appropriate. The format of Level-3 data, calibration data and ancillary data can be chosen depending on the type of data product and the objectives. However, as much as possible standard formats should be used (MPEG, FITS, JPEG2000, CDF, PNG, ...).* |
| CAL | IT | Calibration data | Data format as appropriate. *Not all calibration data are necessarily open to the scientific community.* |
| ANC | IT/SOC | Ancillary data | Data format as appropriate. *Not all ancillary data are necessarily open to the scientific community.* |
| PLN | SOC | Planning data | Files related to mission planning issued by the SOC, for example the E-FECS (see E-FECS ICD). *Not all planning files are necessarily open to the scientific community* |
| LL01 | SOC | LL engineering data, output of LL pipeline | CDF, metadata follow Solar Orbiter standard, with some specifics for LL-01 data: time in OBT, attitude in instrument detector reference frame. |
| LL02 | SOC | Operational LL data, enhanced with S/C HK | CDF, metadata follow Solar Orbiter standard, with some specifics for LL-02 data : time in UTC, attitude in WCS coordinate frame. |
| LL03 | SOC | Visualisation of operational LL data, in "quicklook" format | 'Quicklook' data in PNG or JPEG2000 (details TBC). This level is also used for LL data products derived from (multiple) LL02 products. |

*Note that we do not specify a level for LL TM that has been fully processed and calibrated*

*by the instrument team. These should be classified as 'L2'. Higher level, derived data*

*products are part of 'L3' data.*

## Primary Products Format

The SWA instrument uses the CDF format for its science data products. This section describes the format and record structure of each of the science data file types.

The following information should be given for each of the data products:

* Product name
* Description
* Descriptor
* Free field
* Level
* Dataset dependencies (if any)
* Associated calibration set (if any)
* expected cadence and dataset volume

The definitions of these attributes can be found in the Data Products and Filenames Confluence document (0, section 2.1)

The definitions below shall include all metadata contained in the product, both Solar Orbiter mandatory metadata [AD.01] and Instrument Specific metadata if any. A description of the data content organisation (as described in the aforementioned section of 0) shall be given as well.

The filename will follow this format:

solo\_[DataLevel]\_swa-[Sensor]-[DataType]\_[StartEpoch- EndEpoch]\_[Version].cdf

An example of this is:

solo\_L0\_swa-eas-NM\_YYYYMMDDTHHMMSS- YYYYMMDDTHHMMSS\_V01.cdf

Where StartTime and EndTime are the course seconds from the first and last SCET. It is expected that these files will cover 86400 second periods.

### L0 – Raw data products

*Description of the process used to obtain this type of data*

#### EAS1 normal mode electron counts

This file contains the Normal Mode Electron Counts data product from EAS1. The file format is .cdf.

**Filename**: solo\_L0\_swa-eas1-NMc\_[StartTime-EndTime]\_V01.cdf

**Expected data volume and time resolution**: This file contains the data between the start time and end time in the file name. The start and end times are spacecraft elapsed time (SCET) at 1 second coarse resolution, from the reference point (1 Jan 2000 TBC). The time resolution of the file is nominally 100 seconds. It contains electron counts in 16 bit format covering 64 energies, 32 anodes and 16 deflectors for each time-stamp. It is expected that the file will cover 1 single 24 hour period approximately. In this case there will be 864 records and the file size will be of the order of 61 Mbytes per day.

**Global Attributes**

|  |  |  |
| --- | --- | --- |
| **Name** | **Entry** | **Value** |
| Project | 1 | Solar Orbiter |
| Project | 2 | Cosmic Visions |
| Source Name | 1 | SOLO>Solar Orbiter |
| Discipline | 1 | Space Physics>Interplanetary Studies |
| Data Type | 1 | L0 |
| Descriptor | 1 | SWA-EAS1 |
| Data Version | 1 | 01 |
| Software Version | 1 | 01.00.00 |
| PI Name | 1 | C. J. Owen |
| PI Affiliation | 1 | MSSL-UCL, University College London |
| Instrument Type | 1 | Space Plasma |
| Mission Group | 1 | Solar Orbiter |
| Logical Source | 1 | SWA\_L0\_EAS1\_data |
| Logical File id | 1 | solo\_L0\_swa-eas1\_NMc\_0000000000\_V01 |
| Logical Source Description | 1 | SWA-EAS1 L0 NM data |
| Rules of Use | 1 | Consult with MSSL-UCL before using |
| Generated by | 1 | MSSL |
| Generation date | 1 | YYYY-MM-DDTHH:MN:SS |
| Mods | 1 | V01 First Version |
| Level | 1 | L0 |
| Instrument | 1 | SWA-EAS>Solar-Wind-Analyser-Electron-Analyser-System |

**Variables**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variable\_Name** | **Data\_type** | **DIMS** | **SIZES** | **R\_VARY** | **D\_VARY** |
| SWA\_EAS1\_SCET | CDF\_Double | 1 | 1 | T | F |
| **Attribute Name** | **Data Type** | **Value** | | | |
| FIELDNAM | CDF\_CHAR | SCET | | | |
| CATDESC | CDF\_CHAR | Elapsed time of onboard clock | | | |
| DISPLAY\_TYPE | CDF\_CHAR | Time Series | | | |
| FILLVAL | CDF\_REAL8 | -1E31 | | | |
| FORMAT | CDF\_CHAR | f14.3 | | | |
| LABLAXIS | CDF\_CHAR | Spacecraft Elapsed Time (Ticks) | | | |
| UNITS | CDF\_CHAR | Ticks | | | |
| VALIDMIN | CDF\_REAL8 | 0 | | | |
| VALIDMAX | CDF\_REAL8 | 4294967295.999 | | | |
| SCALETYP | CDF\_CHAR | Linear | | | |
| SCALEMIN | CDF\_REAL8 | TBD | | | |
| SCALEMAX | CDF\_REAL8 | TBD | | | |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variable\_Name** | **Data\_type** | **DIMS** | **SIZES** | **R\_VARY** | **D\_VARY** |
| SWA\_EAS1-NMc | CDF\_Float | 3 | 32,16,63 | T | F,F,F |
| **Attribute Name** | **Data Type** | **Value** | | | |
| FIELDNAM | CDF\_CHAR | SWA\_EAS1-NMc | | | |
| CATDESC | CDF\_CHAR | Normal mode electron counts from EAS1 | | | |
| DEPEND\_0 | CDF\_CHAR | SWA\_EAS1\_SCET | | | |
| DEPEND\_1 | CDF\_CHAR | SWA\_EAS1\_energy array | | | |
| DEPEND\_2 | CDF\_CHAR | SWA\_EAS1\_anode array | | | |
| DEPEND\_3 | CDF\_CHAR | SWA\_EAS1\_deflector array | | | |
| DISPLAY\_TYPE | CDF\_CHAR | Spectrogram | | | |
| FILLVAL | CDF\_REAL8 | -1E31 | | | |
| FORMAT | CDF\_CHAR | f14.4 | | | |
| LABLAXIS | CDF\_CHAR | Electron Counts | | | |
| UNITS | CDF\_CHAR | Total Counts | | | |
| VALIDMIN | CDF\_REAL8 | TBD | | | |
| VALIDMAX | CDF\_REAL8 | TBD | | | |
| SCALETYP | CDF\_CHAR | Log | | | |
| SCALEMIN | CDF\_REAL8 | TBD | | | |
| SCALEMAX | CDF\_REAL8 | TBD | | | |
| ACC\_TIME | CDF\_CHAR | 1 s | | | |
| COORDINATE\_SYSTEM | CDF\_CHAR | EAS1 | | | |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variable\_Name** | **Data\_type** | **DIMS** | **SIZES** | **R\_VARY** | **D\_VARY** |
| EAS1\_energy array | CDF\_CHAR | 1 | 63 | F | F |
| **Attribute Name** | **Data Type** | **Value** | | | |
| FIELDNAM | CDF\_CHAR | EAS1\_energy\_array | | | |
| CATDESC | CDF\_CHAR | The energy array used | | | |
| FORMAT | CDF\_CHAR | f14.4 | | | |
| UNITS | CDF\_CHAR | eV | | | |
| VALIDMIN | CDF\_REAL8 | 0 | | | |
| VALIDMAX | CDF\_REAL8 | TBD | | | |
| SCALETYP | CDF\_CHAR | Log | | | |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variable\_Name** | **Data\_type** | **DIMS** | **SIZES** | **R\_VARY** | **D\_VARY** |
| EAS1\_anode array | CDF\_CHAR | 1 | 32 | F | F |
| **Attribute Name** | **Data Type** | **Value** | | | |
| FIELDNAM | CDF\_CHAR | EAS1\_anode\_array | | | |
| CATDESC | CDF\_CHAR | The anode array used | | | |
| FORMAT | CDF\_CHAR | f14.4 | | | |
| UNITS | CDF\_CHAR | Degrees | | | |
| VALIDMIN | CDF\_REAL8 | 0 | | | |
| VALIDMAX | CDF\_REAL8 | 360 | | | |
| SCALETYP | CDF\_CHAR | LINEAR | | | |
| COORDINATE\_SYSTEM | CDF\_CHAR | EAS1 | | | |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variable\_Name** | **Data\_type** | **DIMS** | **SIZES** | **R\_VARY** | **D\_VARY** |
| EAS1\_deflector array | CDF\_CHAR | 1 | 16 | F | F |
| **Attribute Name** | **Data Type** | **Value** | | | |
| FIELDNAM | CDF\_CHAR | EAS1\_deflector\_array | | | |
| CATDESC | CDF\_CHAR | The deflector array used | | | |
| FORMAT | CDF\_CHAR | f14.4 | | | |
| UNITS | CDF\_CHAR | Degrees | | | |
| VALIDMIN | CDF\_REAL8 | -45 | | | |
| VALIDMAX | CDF\_REAL8 | 45 | | | |
| SCALETYP | CDF\_CHAR | LINEAR | | | |
| COORDINATE\_SYSTEM | CDF\_CHAR | EAS1 | | | |

#### EAS1 single strahl electron counts

This file contains the single strahl electron counts data product from EAS1. The file format is .cdf.

**Filename**: solo\_L0\_swa-eas1-SSc\_[StartTime-EndTime]\_V01.cdf

**Expected data volume and time resolution**: This file contains the data between the start time and end time in the file name. The start and end times are spacecraft elapsed time (SCET) at 1 second coarse resolution, from the reference point (1 Jan 2000 TBC). The time resolution of the file is nominally 100 seconds. It contains electron counts in 16 bit format covering 1 energy, 32 anodes and 16 deflectors for each time-stamp. It is expected that the file will cover 1 single 24 hour period approximately. In this case there will be 864 records and the file size will be of the order of 1 Mbyte per day.

**Global Attributes**

|  |  |  |
| --- | --- | --- |
| **Name** | **Entry** | **Value** |
| Project | 1 | Solar Orbiter |
| Project | 2 | Cosmic Visions |
| Source Name | 1 | SOLO>Solar Orbiter |
| Discipline | 1 | Space Physics>Interplanetary Studies |
| Data Type | 1 | L0 |
| Descriptor | 1 | SWA-EAS\_L0-data |
| Data Version | 1 | 01 |
| Software Version | 1 | 01.00.00 |
| PI Name | 1 | C. J. Owen |
| PI Affiliation | 1 | MSSL-UCL, University College London |
| Instrument Type | 1 | Space Plasma |
| Mission Group | 1 | Solar Orbiter |
| Logical Source | 1 | SWA\_L0\_EAS1\_data |
| Logical File id | 1 | solo\_L0\_swa-eas1\_SSc\_0000000000\_V01 |
| Logical Source Description | 1 | SWA-EAS1 L0 SS data |
| Rules of Use | 1 | Consult with MSSL-UCL before using |
| Generated by | 1 | MSSL |
| Generation date | 1 | YYYY-MM-DDTHH:MN:SS |
| Mods | 1 | V01 First Version |
| Level | 1 | L0 |
| Instrument | 1 | SWA-EAS>Solar-Wind-Analyser-Electron-Analyser-System |

**Variables**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variable\_Name** | **Data\_type** | **DIMS** | **SIZES** | **R\_VARY** | **D\_VARY** |
| SWA\_EAS1\_SCET | CDF\_Double | 1 | 1 | T | F |
| **Attribute Name** | **Data Type** | **Value** | | | |
| FIELDNAM | CDF\_CHAR | SCET | | | |
| CATDESC | CDF\_CHAR | Elapsed time of onboard clock | | | |
| DISPLAY\_TYPE | CDF\_CHAR | Time Series | | | |
| FILLVAL | CDF\_REAL8 | -1E31 | | | |
| FORMAT | CDF\_CHAR | f14.3 | | | |
| LABLAXIS | CDF\_CHAR | Spacecraft Elapsed Time (Ticks) | | | |
| UNITS | CDF\_CHAR | Ticks | | | |
| VALIDMIN | CDF\_REAL8 | 0 | | | |
| VALIDMAX | CDF\_REAL8 | 4294967295.999 | | | |
| SCALETYP | CDF\_CHAR | Linear | | | |
| SCALEMIN | CDF\_REAL8 | TBD | | | |
| SCALEMAX | CDF\_REAL8 | TBD | | | |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variable\_Name** | **Data\_type** | **DIMS** | **SIZES** | **R\_VARY** | **D\_VARY** |
| SWA\_EAS1-SSc | CDF\_Float | 2 | 32,16 | T | F,F |
| **Attribute Name** | **Data Type** | **Value** | | | |
| FIELDNAM | CDF\_CHAR | SWA\_EAS1-SSc | | | |
| CATDESC | CDF\_CHAR | The single strahl electron counts data from EAS1 | | | |
| DEPEND\_0 | CDF\_CHAR | SWA\_EAS1\_SCET | | | |
| DEPEND\_1 | CDF\_CHAR | SWA\_EAS1\_energy value | | | |
| DEPEND\_2 | CDF\_CHAR | SWA\_EAS1\_anode array | | | |
| DEPEND\_3 | CDF\_CHAR | SWA\_EAS1\_deflector array | | | |
| DISPLAY\_TYPE | CDF\_CHAR | Spectrogram | | | |
| FILLVAL | CDF\_REAL8 | -1E31 | | | |
| FORMAT | CDF\_CHAR | f14.4 | | | |
| LABLAXIS | CDF\_CHAR | Electron Counts | | | |
| UNITS | CDF\_CHAR | Total Counts | | | |
| VALIDMIN | CDF\_REAL8 | TBD | | | |
| VALIDMAX | CDF\_REAL8 | TBD | | | |
| SCALETYP | CDF\_CHAR | Log | | | |
| SCALEMIN | CDF\_REAL8 | TBD | | | |
| SCALEMAX | CDF\_REAL8 | TBD | | | |
| ACC\_TIME | CDF\_CHAR | 1 ms | | | |
| COORDINATE\_SYSTEM | CDF\_CHAR | SO\_RTP | | | |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variable\_Name** | **Data\_type** | **DIMS** | **SIZES** | **R\_VARY** | **D\_VARY** |
| EAS1\_energy value | CDF\_CHAR | 1 | 1 | F | F |
| **Attribute Name** | **Data Type** | **Value** | | | |
| FIELDNAM | CDF\_CHAR | EAS1\_single strahl energy | | | |
| CATDESC | CDF\_CHAR | The single strahl energy used | | | |
| FORMAT | CDF\_CHAR | f14.4 | | | |
| UNITS | CDF\_CHAR | eV | | | |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variable\_Name** | **Data\_type** | **DIMS** | **SIZES** | **R\_VARY** | **D\_VARY** |
| EAS1\_anode array | CDF\_CHAR | 1 | 32 | F | F |
| **Attribute Name** | **Data Type** | **Value** | | | |
| FIELDNAM | CDF\_CHAR | EAS1\_anode\_array | | | |
| CATDESC | CDF\_CHAR | The anode array used | | | |
| FORMAT | CDF\_CHAR | f14.4 | | | |
| UNITS | CDF\_CHAR | Degrees | | | |
| VALIDMIN | CDF\_REAL8 | 0 | | | |
| VALIDMAX | CDF\_REAL8 | 360 | | | |
| SCALETYP | CDF\_CHAR | LINEAR | | | |
| COORDINATE\_SYSTEM | CDF\_CHAR | EAS1 | | | |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variable\_Name** | **Data\_type** | **DIMS** | **SIZES** | **R\_VARY** | **D\_VARY** |
| EAS1\_deflector array | CDF\_CHAR | 1 | 16 | F | F |
| **Attribute Name** | **Data Type** | **Value** | | | |
| FIELDNAM | CDF\_CHAR | EAS1\_energy\_array | | | |
| CATDESC | CDF\_CHAR | The energy array used | | | |
| FORMAT | CDF\_CHAR | f14.4 | | | |
| UNITS | CDF\_CHAR | Degrees | | | |
| VALIDMIN | CDF\_REAL8 | -45 | | | |
| VALIDMAX | CDF\_REAL8 | 45 | | | |
| SCALETYP | CDF\_CHAR | LINEAR | | | |
| COORDINATE\_SYSTEM | CDF\_CHAR | EAS1 | | | |

#### EAS1 Triggered Mode Counts

This file contains the triggered mode electron counts data product from EAS1. The file format is .cdf.

**Filename**: solo\_L0\_swa-eas1-TMc\_[StartTime-EndTime]\_V01.cdf

**Expected data volume and time resolution**: This file contains the data between the start time and end time in the file name. The start and end times are spacecraft elapsed time (SCET) at 1 second coarse resolution, from the reference point (1 Jan 2000 TBC). The time resolution of the file is nominally 1 second for 5 minutes. It contains electron counts in 16 bit format covering 64 energies, 32 anodes and 16 deflectors for each time-stamp. It is expected that the file will cover 1 single triggered event. In this case there will be 300 records and the file size will be of the order of 21 Mbytes per event.

**Global Attributes**

|  |  |  |
| --- | --- | --- |
| **Name** | **Entry** | **Value** |
| Project | 1 | Solar Orbiter |
| Project | 2 | Cosmic Visions |
| Source Name | 1 | SOLO>Solar Orbiter |
| Discipline | 1 | Space Physics>Interplanetary Studies |
| Data Type | 1 | L0 |
| Descriptor | 1 | SWA-EAS\_L0-data |
| Data Version | 1 | 01 |
| Software Version | 1 | 01.00.00 |
| PI Name | 1 | C. J. Owen |
| PI Affiliation | 1 | MSSL-UCL, University College London |
| Instrument Type | 1 | Space Plasma |
| Mission Group | 1 | Solar Orbiter |
| Logical Source | 1 | SWA\_L0\_EAS1\_data |
| Logical File id | 1 | solo\_L0\_swa-eas1\_HK\_0000000000\_V01 |
| Logical Source Description | 1 | SWA-EAS1 L0 HK data |
| Rules of Use | 1 | Consult with MSSL-UCL before using |
| Generated by | 1 | MSSL |
| Generation date | 1 | YYYY-MM-DDTHH:MN:SS |
| Mods | 1 | V01 First Version |
| Level | 1 | L0 |
| Instrument | 1 | SWA-EAS>Solar-Wind-Analyser-Electron-Analyser-System |

**Variables**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variable\_Name** | **Data\_type** | **DIMS** | **SIZES** | **R\_VARY** | **D\_VARY** |
| SWA\_EAS1\_SCET | CDF\_Double | 1 | 1 | T | F |
| **Attribute Name** | **Data Type** | **Value** | | | |
| FIELDNAM | CDF\_CHAR | SCET | | | |
| CATDESC | CDF\_CHAR | Elapsed time of onboard clock | | | |
| DISPLAY\_TYPE | CDF\_CHAR | Time Series | | | |
| FILLVAL | CDF\_REAL8 | -1E31 | | | |
| FORMAT | CDF\_CHAR | f14.3 | | | |
| LABLAXIS | CDF\_CHAR | Spacecraft Elapsed Time (Ticks) | | | |
| UNITS | CDF\_CHAR | Ticks | | | |
| VALIDMIN | CDF\_REAL8 | 0 | | | |
| VALIDMAX | CDF\_REAL8 | 4294967295.999 | | | |
| SCALETYP | CDF\_CHAR | Linear | | | |
| SCALEMIN | CDF\_REAL8 | TBD | | | |
| SCALEMAX | CDF\_REAL8 | TBD | | | |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variable\_Name** | **Data\_type** | **DIMS** | **SIZES** | **R\_VARY** | **D\_VARY** |
| SWA\_EAS1-NMc | CDF\_Float | 3 | 32,16,63 | T | F,F,F |
| **Attribute Name** | **Data Type** | **Value** | | | |
| FIELDNAM | CDF\_CHAR | SWA\_EAS1-NMc | | | |
| CATDESC | CDF\_CHAR | Normal mode electron counts from EAS1 | | | |
| DEPEND\_0 | CDF\_CHAR | SWA\_EAS1\_SCET | | | |
| DEPEND\_1 | CDF\_CHAR | SWA\_EAS1\_energy array | | | |
| DEPEND\_2 | CDF\_CHAR | SWA\_EAS1\_anode array | | | |
| DEPEND\_3 | CDF\_CHAR | SWA\_EAS1\_deflector array | | | |
| DISPLAY\_TYPE | CDF\_CHAR | Spectrogram | | | |
| FILLVAL | CDF\_REAL8 | -1E31 | | | |
| FORMAT | CDF\_CHAR | f14.4 | | | |
| LABLAXIS | CDF\_CHAR | Electron Counts | | | |
| UNITS | CDF\_CHAR | Total Counts | | | |
| VALIDMIN | CDF\_REAL8 | TBD | | | |
| VALIDMAX | CDF\_REAL8 | TBD | | | |
| SCALETYP | CDF\_CHAR | Log | | | |
| SCALEMIN | CDF\_REAL8 | TBD | | | |
| SCALEMAX | CDF\_REAL8 | TBD | | | |
| ACC\_TIME | CDF\_CHAR | 1 s | | | |
| COORDINATE\_SYSTEM | CDF\_CHAR | EAS1 | | | |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variable\_Name** | **Data\_type** | **DIMS** | **SIZES** | **R\_VARY** | **D\_VARY** |
| EAS1\_energy array | CDF\_CHAR | 1 | 63 | F | F |
| **Attribute Name** | **Data Type** | **Value** | | | |
| FIELDNAM | CDF\_CHAR | EAS1\_energy\_array | | | |
| CATDESC | CDF\_CHAR | The energy array used | | | |
| FORMAT | CDF\_CHAR | f14.4 | | | |
| UNITS | CDF\_CHAR | eV | | | |
| VALIDMIN | CDF\_REAL8 | 0 | | | |
| VALIDMAX | CDF\_REAL8 | TBD | | | |
| SCALETYP | CDF\_CHAR | Log | | | |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variable\_Name** | **Data\_type** | **DIMS** | **SIZES** | **R\_VARY** | **D\_VARY** |
| EAS1\_anode array | CDF\_CHAR | 1 | 32 | F | F |
| **Attribute Name** | **Data Type** | **Value** | | | |
| FIELDNAM | CDF\_CHAR | EAS1\_anode\_array | | | |
| CATDESC | CDF\_CHAR | The anode array used | | | |
| FORMAT | CDF\_CHAR | f14.4 | | | |
| UNITS | CDF\_CHAR | Degrees | | | |
| VALIDMIN | CDF\_REAL8 | 0 | | | |
| VALIDMAX | CDF\_REAL8 | 360 | | | |
| SCALETYP | CDF\_CHAR | LINEAR | | | |
| COORDINATE\_SYSTEM | CDF\_CHAR | EAS1 | | | |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variable\_Name** | **Data\_type** | **DIMS** | **SIZES** | **R\_VARY** | **D\_VARY** |
| EAS1\_deflector array | CDF\_CHAR | 1 | 16 | F | F |
| **Attribute Name** | **Data Type** | **Value** | | | |
| FIELDNAM | CDF\_CHAR | EAS1\_deflector\_array | | | |
| CATDESC | CDF\_CHAR | The deflector array used | | | |
| FORMAT | CDF\_CHAR | f14.4 | | | |
| UNITS | CDF\_CHAR | Degrees | | | |
| VALIDMIN | CDF\_REAL8 | -45 | | | |
| VALIDMAX | CDF\_REAL8 | 45 | | | |
| SCALETYP | CDF\_CHAR | LINEAR | | | |
| COORDINATE\_SYSTEM | CDF\_CHAR | EAS1 | | | |

solo\_L0\_swa-eas2-NMc\_[StartTime-EndTime]\_V01.cdf

solo\_L0\_swa-eas2-SSc\_[StartTime-EndTime]\_V01.cdf

solo\_L0\_swa-eas2-TMc\_[StartTime-EndTime]\_V01.cdf

solo\_L0\_swa-eas2-ENG\_[StartTime-EndTime]\_V01.cdf

solo\_L0\_swa-eas-MOM\_[StartTime-EndTime]\_V01.cdf

solo\_L0\_swa-eas-BMc\_[StartTime-EndTime]\_V01.cdf

solo\_L0\_swa-pas-NM\_[StartTime-EndTime]\_V01.cdf

solo\_L0\_swa-pas-SNAP\_[StartTime-EndTime]\_V01.cdf

solo\_L0\_swa-pas-BM\_[StartTime-EndTime]\_V01.cdf

solo\_L0\_swa-pas-MOM\_[StartTime-EndTime]\_V01.cdf

solo\_L0\_swa-pas-CAL\_[StartTime-EndTime]\_V01.cdf

solo\_L0\_swa-his-TESTn\_[StartTime-EndTime]\_V01.cdf

solo\_L0\_swa-his-TESTb\_[StartTime-EndTime]\_V01.cdf

solo\_L0\_swa-his-CONFIGn\_[StartTime-EndTime]\_V01.cdf

solo\_L0\_swa-his-CONFIGb\_[StartTime-EndTime]\_V01.cdf

solo\_L0\_swa-his-PHAn\_[StartTime-EndTime]\_V01.cdf

solo\_L0\_swa-his-PHAb\_[StartTime-EndTime]\_V01.cdf

solo\_L0\_swa-his-MATRIXn\_[StartTime-EndTime]\_V01.cdf

solo\_L0\_swa-his-MATRIXb\_[StartTime-EndTime]\_V01.cdf

solo\_L0\_swa-his-VDFn\_[StartTime-EndTime]\_V01.cdf

solo\_L0\_swa-his-VDFb\_[StartTime-EndTime]\_V01.cdf

solo\_L0\_swa-his-PRIOn\_[StartTime-EndTime]\_V01.cdf

solo\_L0\_swa-his-PRIOb\_[StartTime-EndTime]\_V01.cdf

solo\_L0\_swa-his-LLn\_[StartTime-EndTime]\_V01.cdf

solo\_L0\_swa-his-LLb\_[StartTime-EndTime]\_V01.cdf

solo\_L0\_swa-his-HK\_[StartTime-EndTime]\_V01.cdf

### L1 – Engineered data products

*Detailed description of the content and format of any engineered data products.*

### L2 – Science data products

*Detailed description of the content and format of the calibrated data products.*

solo\_L2\_swa-eas-NMpsd\_[StartTime-EndTime]\_V01.cdf

solo\_L2\_swa-eas-NMdef\_[StartTime-EndTime]\_V01.cdf

solo\_L2\_swa-eas-SSpsd\_[StartTime-EndTime]\_V01.cdf

solo\_L2\_swa-eas-SSdef\_[StartTime-EndTime]\_V01.cdf

solo\_L2\_swa-eas-TMpsd\_[StartTime-EndTime]\_V01.cdf

solo\_L2\_swa-eas-TMdef\_[StartTime-EndTime]\_V01.cdf

solo\_L2\_swa-eas-BMpsd\_[StartTime-EndTime]\_V01.cdf

solo\_L2\_swa-eas-BMdef\_[StartTime-EndTime]\_V01.cdf

solo\_L2\_swa-eas-MOM\_[StartTime-EndTime]\_V01.cdf

solo\_L2\_swa-eas-GMOMnm\_[StartTime-EndTime]\_V01.cdf

solo\_L2\_swa-eas-GMOMtm\_[StartTime-EndTime]\_V01.cdf

solo\_L2\_swa-pas-NMpsd\_[StartTime-EndTime]\_V01.cdf

solo\_L2\_swa-pas-NMdef\_[StartTime-EndTime]\_V01.cdf

solo\_L2\_swa-pas-BMSpsd\_[StartTime-EndTime]\_V01.cdf

solo\_L2\_swa-pas-BMSdef\_[StartTime-EndTime]\_V01.cdf

solo\_L2\_swa-pas-GMomH\_[StartTime-EndTime]\_V01.cdf

solo\_L2\_swa-pas-GMomHe\_[StartTime-EndTime]\_V01.cdf

solo\_L2\_swa-his-ElemAbun\_[StartTime-EndTime]\_V01.cdf

solo\_L2\_swa-his-IonChState\_[StartTime-EndTime]\_V01.cdf

solo\_L2\_swa-his-ChStateDist\_[StartTime-EndTime]\_V01.cdf

solo\_L2\_swa-his-KinProp\_[StartTime-EndTime]\_V01.cdf

solo\_L2\_swa-his-VelDist\_[StartTime-EndTime]\_V01.cdf

### L3 – Higher level data products

*Detailed description of the content and format of the derived data products.*

TBD

solo\_L3\_swa-eas-NMpa\_[StartTime-EndTime]\_V01.cdf

solo\_L3\_swa-eas-TMpa\_[StartTime-EndTime]\_V01.cdf

solo\_L3\_swa-eas-MOMred\_[StartTime-EndTime]\_V01.cdf

### CAL – Calibration data products

*Detailed description of the content and format of the calibration data products.*

### ANC – Ancillary data products

*Detailed description of the content and format of the Ancilliary data products.*

#### SPICE kernels

#### Mag Data

#### RPW data

# SWA Data products matrix

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Product Name | Description | Descriptor | Free field | Level |
|  | Single Energy 2D VDF (Low Laterncy) |  |  |  |
|  | On board Electron Moments (4s) |  |  |  |
|  | Full 3D VDF |  |  |  |
|  | Burst Mode |  |  |  |
|  | Pitch angle distributions |  |  |  |
|  | On Ground Moments |  |  |  |
|  | House keeping |  |  |  |
|  |  |  |  |  |
|  | Single Energy 2D VDF (Low Laterncy) |  |  |  |
|  | On board Electron Moments (4s) |  |  |  |
|  | Full 3D VDF |  |  |  |
|  | Burst Mode |  |  |  |
|  | Pitch angle distributions |  |  |  |
|  | House keeping |  |  |  |
|  |  |  |  |  |
|  | 2x Charge State Ratios |  |  |  |
|  | 2x Rate spectra |  |  |  |
|  | Normal Mode Rates |  |  |  |
|  | Normal Mode PHA's |  |  |  |
|  | Burst Mode Rates |  |  |  |
|  | Burst Mode PHA's |  |  |  |
|  | House keeping |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  | Ion Moments (4s) |  |  |  |
|  | 3D VDFs (4 sec cadence) |  |  |  |
|  | House keeping |  |  |  |

Table . SWA science data product