Cluster Active Archive:

Interface Control Document for PEA

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DOCUMENT CHANGE RECORD

Issue	RID/Ref	Details
1.0		First Draft
2.0		Document updated to reflect major update in file format
3.0		Addition of CPCMOM, some reorganisation in 5.2 Minor edits throughout for spelling and grammar, formatting
4.0		Reorganised section 3.5. Addition of section 3.6, including MOMENTS, responses to CAA review (Appendix A). Minor corrections/updates in 3.5.7, 5.1.6, 5.2.6, 5.2.7.5, 5.2.7.6 New section 3.7 Deletion section 5.3 (ground generated data), 5.4 (Graphical data)
4.1		Minor corrections/updates in 3.5.2.1, 5.2.7.5, 5.2.7.6
5.0		Inclusion of PITCH_SPIN
6.0		Made the document more concise; use of a new Appendix A to describe common header files; move much of the material explaining metadata variables to a new Appendix B, added Reference section at the front
6.1		Updates to status parameters material (7.7) Some editing requested by H. Laakso to improve clarity throughout the document
6.2		Updates concerning broken anodes (7.7.2) and times when onboard pitch angle selection was not working well (3.5.2.1) and C3 telemetry re-allocation (3.5.1.2 &3)
6.3		Updates to PITCH_3D* (3.7.3.2) and Quality Control Procedures (4.4)
6.4		Updates to data product specification (5.2.6) and Status_WarningPartialCoverage (7.7.20) Some editing requested by H. Laakso to improve clarity. Removal of Status_MultiplePopulations as a possible status parameter

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1 PURPOSE

The purpose of this document is to provide the detailed specification of the Cluster PEACE data products in the ESA Cluster Active Archive (CAA).

The scientific rationale underpinning the CAA activities is as follows:

- Maximise the scientific return from the mission by making all Cluster data available to the worldwide scientific community.
- Ensure that the unique data set returned by the Cluster mission is preserved in a stable, long-term archive for scientific analysis beyond the end of the mission.
- Provide this archive as a major contribution by ESA and the Cluster science community to the International Living With a Star programme.

2 POINTS OF CONTACT

For the operation of archiving the high-resolution data from PEACE the following contacts have been agreed:

- as scientific correspondents, H.Laakso/C.P. Escoubet/M.G.G.T.Taylor for the CAA and A.N. Fazakerley for PEACE,
- as technical correspondents, C. Perry and H. Laakso for the CAA and N. Doss for PEACE.
- as managerial correspondents, H. Laakso for the CAA and A.N. Fazakerley for PEACE.

3 INSTRUMENT DESCRIPTION

3.1 Science Objectives

The science objectives of a single Cluster instrument cannot be fully separated from the objectives of the mission as a whole; the four spacecraft flotilla is an unparalleled space plasma observatory able to characterise the local plasma more completely than any previous mission. The science objectives are thus rather broad, since the Cluster quartet brings new tools to examine a broad range of science questions in the magnetosphere, magnetotail, cusp, magnetosheath, bowshock and solar wind.

The Plasma Electron and Current Experiment (PEACE) measurements of the thermal electron plasma population enable characterisation of the local plasma – its density, bulk flow, electron temperature – and electron pitch angle data reveal whether the region is magnetically connected to regions of electron acceleration or lies between magnetic mirrors. PEACE electron data reveals whether electron pitch angle or energy scattering processes are active, for example as wave-particle interactions occur. Good quality moments of the electron distribution may also be used to study the contribution of electrons to currents in key regions (e.g. magnetotail current sheet, auroral regions, reconnection sites). The four spacecraft capability allows determination of the three-dimensional motion of plasma boundaries (which may not always have a corresponding magnetic signature) and probing of three dimensional structures such as Flux Transfer Events or the magnetotail plasmasheet, where electrons on nearby field lines may have had quite different recent histories. The dataset is key to studies of plasma boundary regions (magnetopause, bowshock, cusp etc.) and how mass, momentum and energy are transferred across them.

3.2 Hardware Overview

3.2.1 Introduction

Each Cluster spacecraft carries an identical PEACE instrument, consisting of two sensors, HEEA and LEEA and a data processing unit, the DPU (Johnstone et al, 1997; Fazakerley et al., in preparation 2006).

The Low Energy Electron Analyser (LEEA) is designed to specialise in coverage of the very lowest electron energies (< 10 eV) but is also capable of covering the full energy range up to ~26 keV. Apart from precautions to minimise the detection of unwanted low energy photoelectrons, LEEA has a geometric factor appropriate for the higher fluxes usually found at lower energies. The High Energy Electron Analyser (HEEA) has a larger geometric factor which extends the dynamic range of the combination of sensors and can also be operated over the full energy range from 0.6 eV to 26.5 keV.

Both sensors are of the same basic type consisting of hemispherical electrostatic analysers of the so-called Top Hat type and an annular microchannel plate with a position sensitive readout as detector. Unlike the CIS sensors, which have a field of view of 360°, HEEA and LEEA each have a field of view of only 180°, which enables the detector to be mounted so that it views radially from the spacecraft. The pair of sensors are mounted opposite to each other on the spacecraft so that they cover the complete angular range in a half rotation of the spacecraft (Figure 1). The radial viewing minimises the access of secondary electrons and photoelectrons produced on the surface of the spacecraft into the aperture of the sensor.

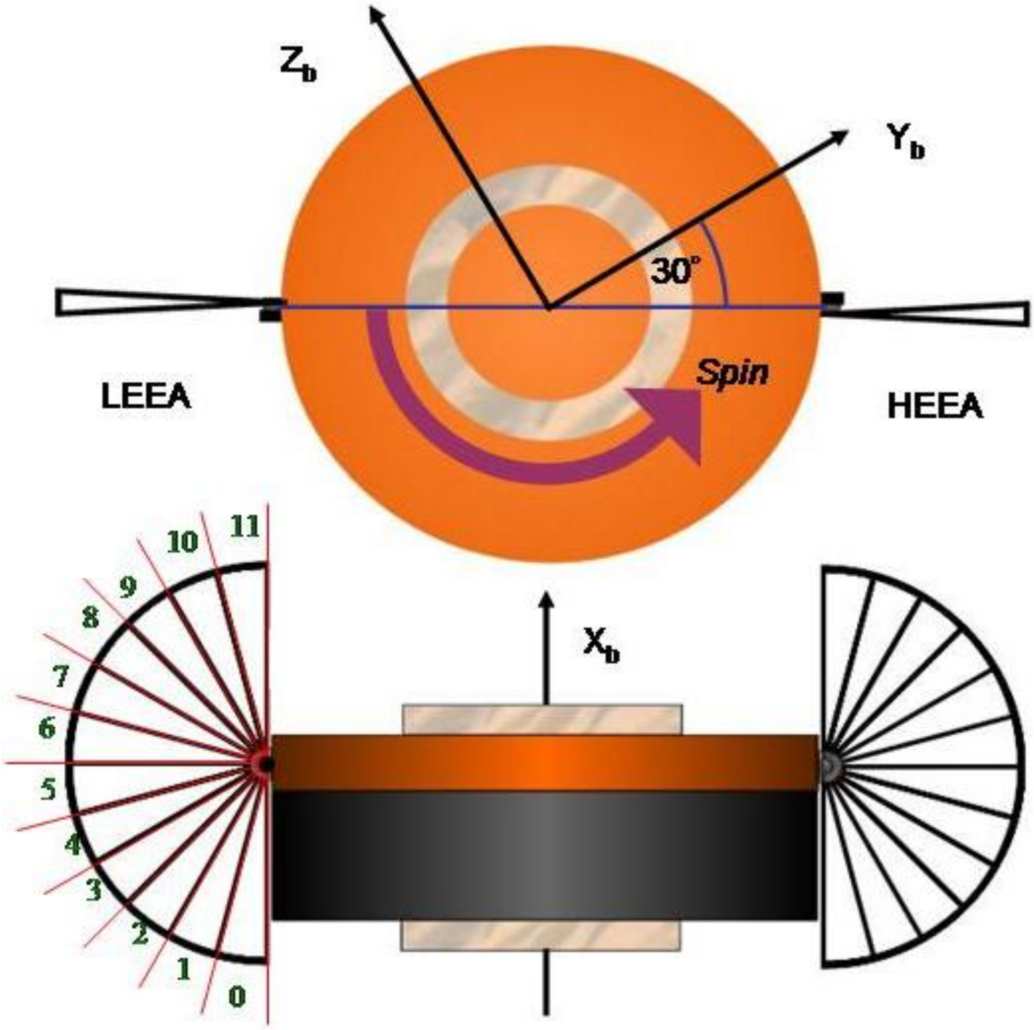


Figure 1. The physical deployment of the Sensors on the spacecraft. The spacecraft body coordinate system is shown (X_b, Y_b, Z_b). The sensor numbering with respect to the spin axis is also indicated, e.g. zone 0 looks towards $-X_b$, and sees electrons with velocities roughly along the spin axis direction, $+X_b$.

3.2.2 The Accumulation Time

The basic measurement made by PEACE is the number of counted electrons per accumulation time.

The satellite spin period, T_{spin}, is subdivided into 1024 equal parts, and each part has duration T_{acc}, the accumulation time. For a nominal 4 second spin, T_{acc} ~ 3.9 millseconds.

The spin period and thus the accumulation time are expected to be slightly different from spacecraft to spacecraft. The spin start time also varies from spacecraft to spacecraft, since no deliberate control of spacecraft spin phase was attempted.

The spin start time used by PEACE differs from the spin interval starting with a sun pulse signal from the spacecraft sun sensor, as is explained further in 3.2.6 below.

3.2.3 Energy Coverage and Resolution

The energy range of the instrument is nominally from 0.6 eV to 26,460 eV.

The Sensors can each make measurements at 88 distinct non-zero levels (see Table 1). The first 16 energy levels are equally spaced linearly in the range from 0.6 eV to 9.5 eV. Levels 16 to 87 inclusive are equally space logarithmically over the rest of the range. An additional three levels (89-91) which are identical to level 88 are defined for technical reasons. Measurements at these fixed energies are possible, but are not generally made during normal science data collection operations.

In normal operation, a selected energy range is sampled several times during each spin. The process is called an energy sweep, during which the energy is continuously varied from a high to a low level, and has duration T_{sweep}.

During a sweep, the measured energy is reduced by one "step" from energy level *n* to level *n-1* in sweep mode LAR or else by two "steps" from energy level *n* to level *n-2* in sweep modes MAR and HAR, during each measurement period T_{acc}. As the energy range is swept rather than stepped, there is no skipping of alternate energy channels in MAR and HAR mode. The instrument sweeps through two energy channels in time T_{acc} in MAR and HAR mode in contrast to sweeping through one energy channel in T_{acc} in LAR mode. Nor does the instrument sit at one energy for most of T_{acc} and then very quickly jump to the next energy. The energy range covered is 60 levels in sweep mode LAR, 30 levels in sweep mode MAR and 15 levels in sweep mode HAR (see Table 2).

A complete sweep also has a "flyback" component during which the Sensor HV is returned to the high value needed for the start of the next measurement sweep. The duration of the flyback differs according to sweep mode. The energy sweeps, including the flybacks, are illustrated in Figure 2.

Typically, the HEEA sensor covers the energy range between levels 88 and 28 in MAR mode, and the LEEA sensor covers the energy range between levels 60 and 0 in MAR mode, but several other approaches have also been used.

3.2.4 Azimuth Angle Coverage and Resolution

During the satellite spin period the satellite rotates through 360°. The angle of rotation between two measurements at the same energy is called the azimuth angle resolution, and is given by 360° x T_{sweep}/T_{spin}.

There are 16 sweeps per spin in sweep mode LAR, 32 in sweep mode MAR and 64 in sweep mode HAR, so that the azimuthal angle resolutions are 22.5°, 11.25° and 5.625° respectively. Hence the terminology, with LAR/MAR/HAR referring to Low/Medium/High Angular Resolution (see Table 2).

The azimuthal acceptance angle is larger for HEEA than LEEA (see Figure 3. The look direction sweeps through only 0.35° during T_{acc}.

A related useful concept is the "basic segment" which has duration 64 T_{acc}. Each spin contains 16 basic segments. The basic segment contains 1 sweep in LAR, 2 sweeps in MAR or 4 sweeps in HAR sweep mode.

3.2.5 Polar Angle Coverage and Resolution

The 180° detector field of view is divided up into 12 equal parts of angular width 15° as illustrated in Figure 1. Measurements are made simultaneously in each of these 12 "polar zones".

In each Sensor there are 12 discrete anodes behind the microchannel plates, which provide the position sensitive readout. Each anode is connected to an amplifier and counter system.

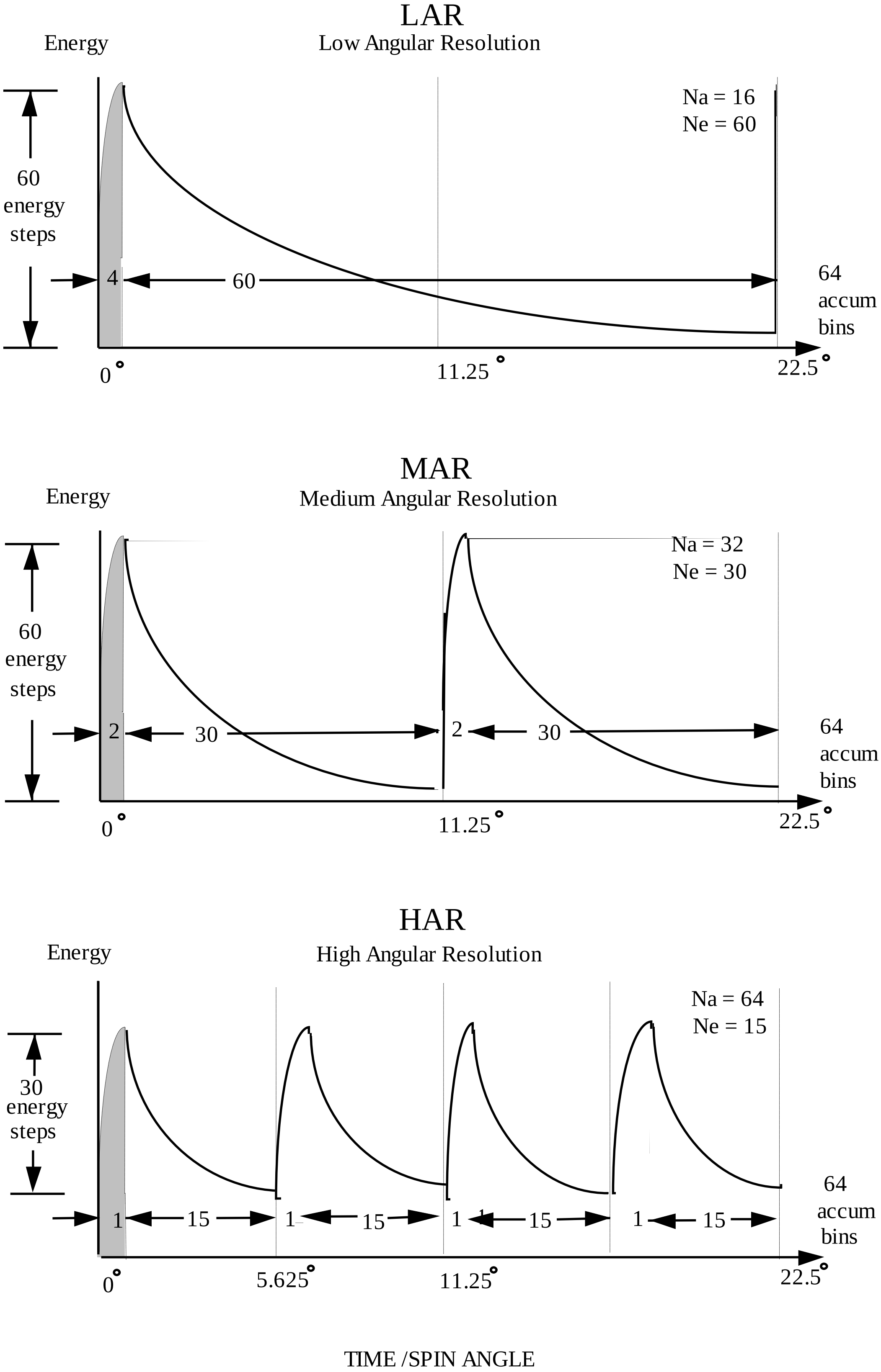


Figure 2. The pattern of the energy sweeps in each of the three sweep modes (flyback in grey, only one flyback interval has been highlighted per sweep mode)

Level	Energy		Level	Energy		Level	Energy
0	0. 000						
1	0. 589		31	47. 349		61	1 324. 082
2	1. 178		32	52. 851		62	1 479. 452
3	1. 768		33	58. 990		63	1 653. 652
4	2. 358		34	66. 394		64	1 846. 569
5	2. 948		35	73. 839		65	2 063. 156
6	3. 538		36	82. 576		66	2 305. 759
7	4. 128		37	92. 630		67	2 576. 960
8	4. 719		38	103. 393		68	2 879. 542
9	5. 310		39	115. 524		69	3 216. 402
10	5. 902		40	129. 055		70	3 593. 675
11	6. 493		41	144. 029		71	4 015. 331
12	7. 085		42	161. 150		72	4 485. 220
13	7. 677		43	179. 825		73	5 011. 577
14	8. 270		44	200. 792		74	5 604. 590
15	8. 862		45	224. 147		75	6 257. 032
16	9. 455		46	250. 707		76	6 990. 199
17	10. 048		47	279. 919		77	7 818. 023
18	11. 236		48	313. 401		78	8 735. 844
19	12. 424		49	349. 918		79	9 752. 292
20	14. 208		50	391. 216		80	10 906. 150
21	15. 399		51	436. 858		81	12 185. 330
22	17. 784		52	488. 011		82	13 597. 360
23	19. 575		53	545. 159		83	15 199. 110
24	21. 968		54	608. 870		84	16 988. 430
25	24. 364		55	680. 739		85	18 978. 890
26	27. 366		56	760. 715		86	21 225. 920
27	30. 375		57	849. 747		87	23 700. 160
28	33. 994		58	948. 966		88	26 460. 000
29	38. 229		59	1 060. 088			
30	42. 477		60	1 184. 895			

Table 1: Approximate electron energy for each fixed energy level. The mean energy of electrons accumulated during a sweep step will lie between the start and end energy levels of the step.

	Energy resolution	Polar resolution	Azimuth resolution	Energy samples	Polar samples	Azimuth samples	Energy Coverage
LAR	1 step /bin	$\pi/12$	$\pi/8$	60 bin	12 bin	16 bin	60 step
		15°	22.5°				
MAR	2 step /bin	$\pi/12$	$\pi/16$	30 bin	12 bin	32 bin	60 step
		15°	11.25°				
HAR	2 step /bin	$\pi/12$	$\pi/32$	15 bin	12 bin	64 bin	30 step
		15°	5.625°				

Table 2: Properties of the Energy Sweep Modes: LAR, MAR and HAR

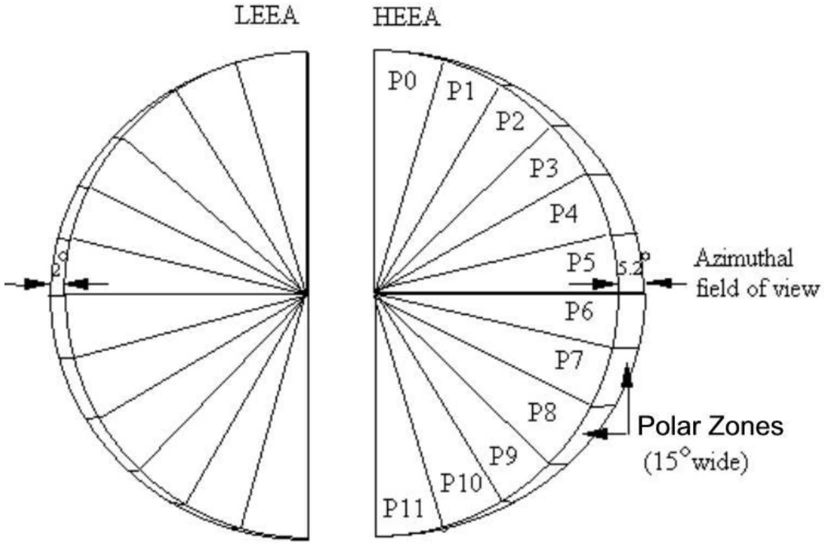


Figure 3. The angular response of the two analysers.

3.2.6 Data Timing and the PEACE Coordinate System

The start of a PEACE spin occurs on reception of a rephased sun pulse. The rephase angle ϕ can be changed on command and can be set to minimise measurements of solar UV generated photoelectrons (at low energy) by ensuring the energy sweep is at a higher energy when the PEACE Sensor apertures look sunwards. The rephase angle used at launch (SPOS = 176) was modified in August 2003 in order to better correspond to the CSDS spin definition (SPOS = 1200). These issues are taken care of during production of the CAA PEACE files.

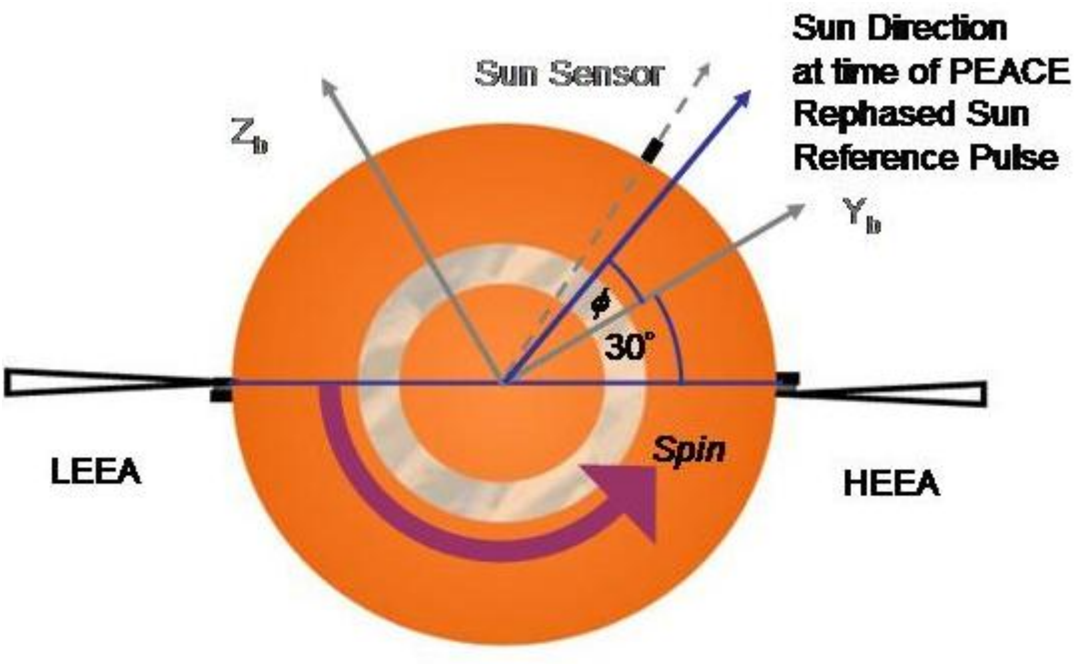


Figure 4. The rephased sun reference pulse.

3.2.7 Electronic Dead Time Correction

A deadtime correction will be performed in the DPU on all count values transmitted from the sensors, to account for electronic deadtime effects which begin to become apparent at fluxes ~ 1MHz per anode.

The DPU will adjust the deadtime algorithm to account for variations in the spin period. It also allows for different deadtimes for each discrete anode to compensate for differences in the amplifiers. These factors can be changed in flight by uplinking new values determined from an analysis of the data. The maximum count output from the deadtime correction is limited to 8032 counts per accumulation by the DPU capacity, corresponding to over 2 MHz per anode.

3.2.8 Detectors

The electron detectors are chevron-pair microchannel plates (MCP) which become effective charge amplifiers when a high voltage (~2 to 3 keV) is placed across them. The primary electrons are accelerated into the MCP by a 150 V bias at the cathode end of the MCP for more efficient operation.

The MCP gain tends to decline as the quantity of measured electrons increases. In order to restore satisfactory gain levels, the HV MCP supply level can be increased through a number of steps, about 60 V apart.

Under sufficiently intense fluxes, the gain may temporarily by reduced below normal levels, leading to underestimation of the measured electron flux. This form of deadtime is not corrected for onboard.

3.2.9 Sensor Geometric Factors

The geometric factors of the two sensors have been chosen so that the instrument spans the required dynamic range. The range is defined by the need to maintain accurate measurements, to avoid the effects of saturation, and to obtain significant count-rates within a short time even in the least dense plasmas. The range of particle flux that has to be measured is 10^6 to 10^{13}(cm^2 s sr keV)$^{-1}$, i.e. a range of seven orders of magnitude. The highest fluxes are expected for energies of a few eV in the solar wind and the magnetosheath. The lowest fluxes will be found at the highest energies, usually > 1 keV, although in the solar wind and tail lobes, these lowest values may even be present starting from energies as low as 100 eV. Within the available resources, the detectors and their front end electronics are capable of coping with only six orders of magnitude therefore we have extended the dynamic range of the measurements by using different geometric factors for the two sensors. The HEEA sensor could saturate at energies of a few 100 eVs in the magnetosheath. However, this saturation will usually fall within the energy range of the sensor overlap and LEEA will still be able to measure the flux.

3.2.10 Special Issues Relating to Low Energy Electron Measurements

3.2.10.1 Spacecraft Electrostatic Potential

The spacecraft is immersed in a plasma of electrons and less mobile ions. Collisions between these particles and the spacecraft produce a net current flow from the spacecraft to the plasma. Emission of secondary electrons caused by the impact of primary electrons or ions slightly reduces the current. In sunlight, and additional current onto the spacecraft is produced by the emission of photo-electrons. The coupled spacecraft-plasma system maintains a current balance, because the electrostatic potential of the spacecraft assumes a value that controls the level of plasma and photoelectron currents. For example, in sunlight, the photocurrent typically dominates, and so to achieve a current balance it must be reduced and the plasma current enhanced. This is achieved when the spacecraft becomes slightly positively charged, so as to reduce the fluxes of photo-electrons from the spacecraft and to increase the flux of plasma electrons to the spacecraft. The spacecraft potential necessarily varies in response to variations of the local plasma density and temperature, and typically vary from a few Volts to several 10’s of Volts.

The spacecraft potential can be controlled and held at a sub-10 eV positive value using the ASPOC instrument which adds a further current to the system, a current away from the spacecraft carried by emitted positive ions. This current helps to balance the photo-current.

The spacecraft potential is important for low energy electron measurements because all plasma electrons approaching the spacecraft will be accelerated by the potential. This must be taken into account when assigning a “measured energy” to detected plasma electrons. If the potential is above say 10 eV, any fine structure in the low energy plasma electron spectrum may be harder to distinguish, as these electrons will be measured in the less finely resolved energy steps in the logarithmically spaced part of the PEACE energy sweep.

3.2.10.2 Electrons Emitted by the Spacecraft

At energies below the spacecraft potential, PEACE detects electrons that have been emitted by the spacecraft body. These are mainly thought to be large fluxes of photoelectrons.

It is possible that PEACE will detect electrons emitted by the spacecraft at energies above the spacecraft potential, if their trajectories take them into the PEACE aperture. This is more likely in the zones with look directions tangential to the spacecraft skin, such as zones 0 and 11, than zones looking outward, such as zones 5 and 6.

3.2.10.3 Internal secondary electrons

At times when the sensor aperture is sun-facing, secondary electrons are generated inside the sensor aperture by solar ultraviolet light. To a lesser extent, such electrons may also be generated at any time by ~1-10 keV electrons. Both sources create electrons with an energy of the order of 1 to 10 eV.

When the analyser is measuring low energies, these electrons generate a background signal. These can be recognised when the spacecraft potential is at a low value, so that external photoelectrons are not obscuring their contribution. The solar UV induced signature is readily recognised due to its spin phase dependence.

The effect of both sources of unwanted electrons have been minimised by the design of the input baffle which consists of a series of thin parallel plates. The only production of internal secondary is by particles or light scattered off the knife-edges of the baffle elements. The electrostatic analyser is also coated in a UV absorbent material to minimise UV photoelectron reflections and hence the number of solar photons which reach the MCP or cause emission of photoelectrons from the analyser structure near the MCP.

3.2.11 Onboard Data Processing

During each spin, the DPU receives 16,384 values from each sensor. After discarding flyback data, and data from the redundant fine zone anodes, this still leaves 11,520 values per sensor. The DPU applies a dead time correction to each one, produces the required data products and delivers them to the spacecraft telemetry handling sub-system. In every spin, the DPU generates the PAD pitch angle data product, using magnetic field data from the magnetometer with an onboard calibration applied by PEACE. It also calculates moments of the electron velocity distributions for up to 6 subsets of the energy range data spread across the two sensors. These moments are not corrected for spacecraft potential. They use a simplified representation of the instrument calibration data.

3.3 Instrument Calibration

3.3.1 Measured Energy

The HV sweep generator performance was verified at each fixed level during ground testing. In addition, detailed tests of the voltage profile during sweeping operations were carried out and analysed, showing differences between the LAR profile and the MAR/HAR profile,

Tests with an electron beam were used to establish the k-factor, which relates the energy of electrons accepted by the sensor analyser to the voltage on the analyser hemispheres. Together with the HV sweep generator characteristics, this enables us to define the energy at the beginning and end of each accumulation interval, and also to calculate the representative energy admitted during the accumulation interval.

In order to deal with data products where measured data from two or four energy measurements are combined (e.g. 3DR) we provide several energy tables.

These energy tables are stored in the Database within the VIDF files, and their representation in the CAA CEF files is discussed in Section 5.

3.3.2 Energy & Angle Response

The instrument response to a beam of electrons may vary with the energy of the beam, due to the analyser geometry factor and due energy dependencies of the MCP response.

The response is also expected to show some variation with polar zone, due to possible variations in the MCP response between different anodes.

A calibration table represents the variations in sensitivity with energy and polar angle, and an additional factor is also used to scale the overall sensitivity.

These values are based on ground calibration and refined with in-flight calibrations, which address both the absolute sensitivity (difficult to measure on the ground) and in-flight evolution of the performance – in particular related to variations in MCP gain. It is expected that these data will be revised during the CAA lifetime.

3.4 Data Processing Chain

PEACE raw data received from ESOC is first decompressed and converted to IDFS format (Level 1 data) using PEACE-specific software.

The IDFS Moms_L2 moments (used to make CSDS PP/SP data) and SPINPAD data products are generated from the onboard moments sums and the onboard pitch angle respectively. Calibration knowledge is applied at the time of generation of SPINPAD, and of MOMS_L2.

Potential corrected moments data are calculated using “peacemoments” software and then ingested to the IDFS database as data in scientific units.

CAA moments will be produced in a dedicated activity when corresponding calibrations are at a sufficiently high quality.

3.5 Instrument Data Products : Generated Onboard

PEACE data products are formally defined in the PEACE User Manual Appendix D, Science Telemetry Format Document. See also "The Scientist's Guide to Cluster PEACE".

3.5.1 Three Dimensional (3-D) Distributions Data

3.5.1.1 3DF Full Resolution 3-D Distribution

At energies below the spacecraft potential, PEACE detects electrons that have been emitted by the spacecraft body. These are mainly thought to be large fluxes of photoelectrons.

The 3DF data product always contains both HEEA and LEEA data.

All measured values collected during a single satellite spin are included.

3DF data are provided by the sensors to the DPU, but are rarely transmitted to the Earth, usually only for dedicated in-flight calibration intervals, mostly during Burst Mode spacecraft telemetry operations. Normally 3DF is reduced to smaller products for transmission, depending on the instrument mode.

The total number of measured values per spin is 23,040, distributed among energy, polar and azimuths as follows (depending on sweep mode);

LAR	60e x 12p x 16a x 2s
MAR	30e x 12p x 32a x 2s
HAR	15e x 12p x 64a x 2s

where "e" is the number of energies sampled per sweep; "p" is the number of polar zones, "a" is the number of sweeps (azimuths) per spin and "s" is the number of sensors

The error range associated with compression/decompression for transmission is, at worst, ± 1.5%.

The 3DX distribution (see below) allows the option of transmitting a single sensor-only 3DF.

3.5.1.2 3DX Flexible Reduced Resolution 3-D Distribution

Further options for transmitting reduced resolution 3D data are available, embodied in the 3DX group of data products, described in IDFS as 3DX1, 3DX2; 3DXP1, 3DXP2; 3DXE1, 3DXE2. It is possible to generate and in some situations to transmit two such data products per spin, hence the "1" or "2" suffices. When in use, the suffices "1" and "2" may be used to distinguish between data from different sensors, or data from the same sensor that has been treated differently.

Any 3DX data product is derived from a parent 3DX distribution which can be a spin of data from LEEA, a spin of data from HEEA or a combination of half a spin of data from LEEA with half a spin of data from HEEA (acquired during the same half spin interval). The later case corresponds to a complete 3 dimensional distribution collected in only ~2 seconds.

The parent 3DX distribution consists of a total number of measured values per spin of 11,520, distributed among energy, polar and azimuths as follows (depending on sweep mode);

LAR	60e x 12p x 16a x 1s
MAR	30e x 12p x 32a x 1s
HAR	15e x 12p x 64a x 1s

However after compression the number of data samples depends on the form of 3DX that has been selected.

The 3DXP data products (3DXP1 and 3DXP2) are produced from 3DX by reducing polar angle resolution by a factor 2; by adding data from pairs of neighbouring polar zones for each energy bin I each sweep.

The 3DXE data products (3DXE1 and 3DXE2) are produced from 3DX by reducing energy resolution by a factor 2; by adding data from pairs of neighbouring energy bins, for each polar zone and each sweep.

Further reduction in data product size is possible by choosing to omit to transmit a part of the measured energy range, with the degree of reduction depending on what fraction of the energy range is discarded. This is indicated in support parameters included in the datasets.

In addition, any of these data reduction options can be combined with a choice only to select the basic segments (22.5 degree azimuth sectors) which contain the onboard-determined magnetic field direction, known as 3DX-Pitch-Angle (3DXPA). There are 16 basic segments to a spin, and during this mode only the two basic segments that contain the parallel and anti-parallel pitch angles are returned. (Each basic segment may contain 1, 2 or 4 energy sweeps depending on sweep mode.)

In principle, a very large number of 3DX distributions can be constructed, although in practice only a relatively small number of 3DX distributions are used.

Generally speaking, 3DX distributions are only transmitted during Burst Mode spacecraft telemetry operations. Typically, for spacecraft 1, and for spacecraft 2, 3 and 4 before telemetry reallocation from CIS, CIS & EDI respectively was implemented (see 3.5.1.3. below), 3DXP1 data will be produced with a reduced energy range coverage from one sensor while 3DR is produced from the other. For spacecraft 2, 3 and 4, after telemetry reallocation was implemented, 3DXP1 and 3DXP2 are usually produced, one data product from each sensor. Also, for spacecraft 2, 3 and 4, 3DX1 may occasionally be transmitted, data from only one sensor and no 3D data from the other sensor – this is equivalent to a single sensor 3DF. A further variation, used sometimes to support solar wind studies, is to send 3DXP1 from a sensor and a 3DX2 from the same sensor, but using data from only the basic segment containing the magnetic field direction.

The error range associated with compression/decompression for transmission is, at worst, ± 3% for those 3DX data products in which summing over polars or energies has been performed. In all other cases, the error range is ± 1.5%.

3.5.1.3 3DR Standard Reduced Resolution 3-D Distribution

The 3DR data product may contain HEEA data, or LEEA data or both HEEA and LEEA data.

3DR is regularly selected for transmission in Normal Mode spacecraft telemetry operations, although the baseline data rate is low (the 3DR data for most spins cannot be sent). Occasionally, 3DR data from only one sensor may be returned, in order to increase the rate of 3DR data from that sensor.

Improved 3DR data recovery during Normal Mode operations applies for the case of spacecraft 2, where reallocation of CIS telemetry from 25 November 2001 enables 3DR to be sent on almost all spins, and the case of spacecraft 4, where reallocation of EDI telemetry from 21 March 2002 enables 3DR to be sent on roughly one in every 3 spins. Telemetry sharing on spacecraft 2 with RAPID leads to some intervals later in the mission where 3DR is not continuous on spacecraft 2, but reduced to rates similar to spacecraft 4. Roughly speaking this occurred from July 2003 to June 2004, initially on 1 in 4 orbits and later on 1 in 2 orbits (there were also preliminary tests in March 06, 12 and April 07 2003). On 13 June 2010, reallocation of CIS telemetry to PEACE on spacecraft 3 occurred, so that 3DR data became available almost every spin on this spacecraft as well as for spacecraft 2.

3DR from only one sensor is often used during Burst Mode spacecraft telemetry operations, with 3DX data from the other sensor, although once telemetry reallocation was implemented for spacecraft 2, 3 and 4, 3DR was usually replaced by 3DX for both sensors.

3DR represents a standard reduced resolution form of 3DF, in which the number of data samples is reduced by a factor of 8 from 23,040 to 2,880, distributed among energy, polar and azimuths as follows (independent of sweep mode);

LAR/MAR/HAR   15e x 6p x 16a x 2s

This is achieved onboard in slightly different ways for each sweep mode:

LAR:
- (i) Reduce energy resolution by a factor 4, by adding consecutive sets of 4 successive energy samples together (from each energy sweep of 60 measured energy bins, i.e. azimuth angle, in each polar zone).
- (ii) Reduce polar angle resolution by a factor 2, by adding data from pairs of neighbouring polar zones for each reduced resolution energy bin.

MAR:
- (i) Reduce energy resolution by a factor 2, by adding consecutive sets of 2 successive energy samples together (from each energy sweep of 30 measured energy bins, i.e. azimuth angle, in each polar zone).
- (ii) Reduce polar angle resolution by a factor 2, by adding data from pairs of neighbouring polar zones for each reduced resolution energy bin.
- (iii) Reduce azimuth angle resolution by a factor of 2, by adding data from pairs of neighbouring azimuth zones (from 32 measured azimuthal angles) for each reduced resolution energy bin, at each reduced resolution polar bin.

HAR:
- (i) Reduce polar angle resolution by a factor 2, by adding data from pairs of neighbouring polar zones for each energy bin.
- (ii) Reduce azimuth angle resolution by a factor of 4, by adding data from four successive neighbouring azimuth zones (from 64 measured azimuthal angles)for each energy bin, at each reduced resolution polar bin.

Note that the best energy resolution is available in HAR mode for 3DR data.

The error range associated with compression/decompression for transmission is, at worst, $\pm$ 3%.

3.5.2 Pre-Science Data Products

3.5.2.1 PAD Onboard Selected Pitch Angle Distributions

The PAD data product always contains both HEEA and LEEA data.

It is the basis of a pitch angle data product for use by scientists (see 3.6.3).

PAD data is sent routinely in both Normal Mode and Burst Mode spacecraft telemetry operations.

PAD is a subset of measured values collected during a single satellite spin is included, designed to be the minimum number needed to describe the full pitch angle range.

The total number of values per spin is 780, distributed among energy, polar and azimuths as follows (depending on sweep mode);

LAR	30e x 13p x 1a x 2s
MAR	30e x 13p x 1a x 2s
HAR	15e x 13p x 2a x 2s

For LAR, there are 60 measured energy bins; of these, the 30 even numbered bins are included in the even numbered spins, and the odd ones in odd numbered spins.

The magnetic field estimate used to select these data onboard is usually provided by the Inter-Experiment Link from FGM, applied using onboard values of the estimated FGM offset calibrations. Prior to 11 September 2001, the onboard calibration parameters that are applied to raw FGM data were not well optimised, so the onboard pitch angle selection was not so effective as intended. A new uplink of FGM calibration parameters was performed on that date, after which the process worked well. On two occasions this onboard data link provided corrupted FGM data; this occurred in 2002 between 05 - 30 April and between 02 - 24 May for Cluster 2.

Details of how the PAD data product is generated, and of situations where PAD data can mislead the unwary, are given in "The User Guide to the PEACE measurements in the CAA".

The error range associated with compression/decompression for transmission is, at worst, ± 1.5%.

3.5.2.2 OMS Onboard Moment Sums

Onboard moment sums data is sent routinely in both Normal Mode and Burst Mode spacecraft telemetry operations.

It is the basis of a moments data product for use by scientists (see 3.6.1 and 3.6.2).

The moments sums are usually dual sensor data products. The OMS values calculated on board are:

$\int f(v)dv$	1 value
$\int vf(v)dv$	3 values
$\int vvf(v)dv$	6 values
$\int v\left\|v^2\right\| f(v)dv$	3 values

(although the calculations are summations of discrete values and not integrations!) and the total counts making 14 values per distribution. These summations are converted to the usual plasma parameters on the ground. The OMS calculations are based on 3DR and are carried out for (see Figure 5):

- HEEA from its preset level to the start of the LEEA sweep once/spin
- HEEA levels overlapping the LEEA sweep, twice/spin
- LEEA levels overlapping the HEEA sweep, twice/spin
- LEEA from the bottom of the overlap to level 17 (~10 eV), once/spin *

The size of moment distribution is:

14 values x 16 bit range x 6 sets per spin = 1344 bits per spin

Moments are not corrected on board for interference from either WHISPER or EDI.

No onboard moments are calculated with data below level 17 (~ 10 eV). Ideally the spacecraft potential will lie at a lower energy, the validity of this assumption can be checked using LER (see 3.5.3), and this approach avoids inclusion of photoelectrons in the calculated moments sums. Any ambient plasma between a lower potential and ~10 eV is however not included in the calculation.

It is often the case that the spacecraft potential lies above 10 eV. It may be that only the "bottom" region is contaminated by photoelectrons and could be discarded without major error, but sometimes the "overlap" regions is also affected. In such cases, the density moment is unusually high. Note also that the onboard moments are not corrected for the effects of spacecraft potential.

The process of transmitting data from the spacecraft to the ground involves compressing and decompressing the data, which can introduce an error. The difference may be very small, depending on the value to be telemetered, but an upper limit can be assigned for the worst case. For values in the MOM-D data product the worst case error range is ± 0.4%.

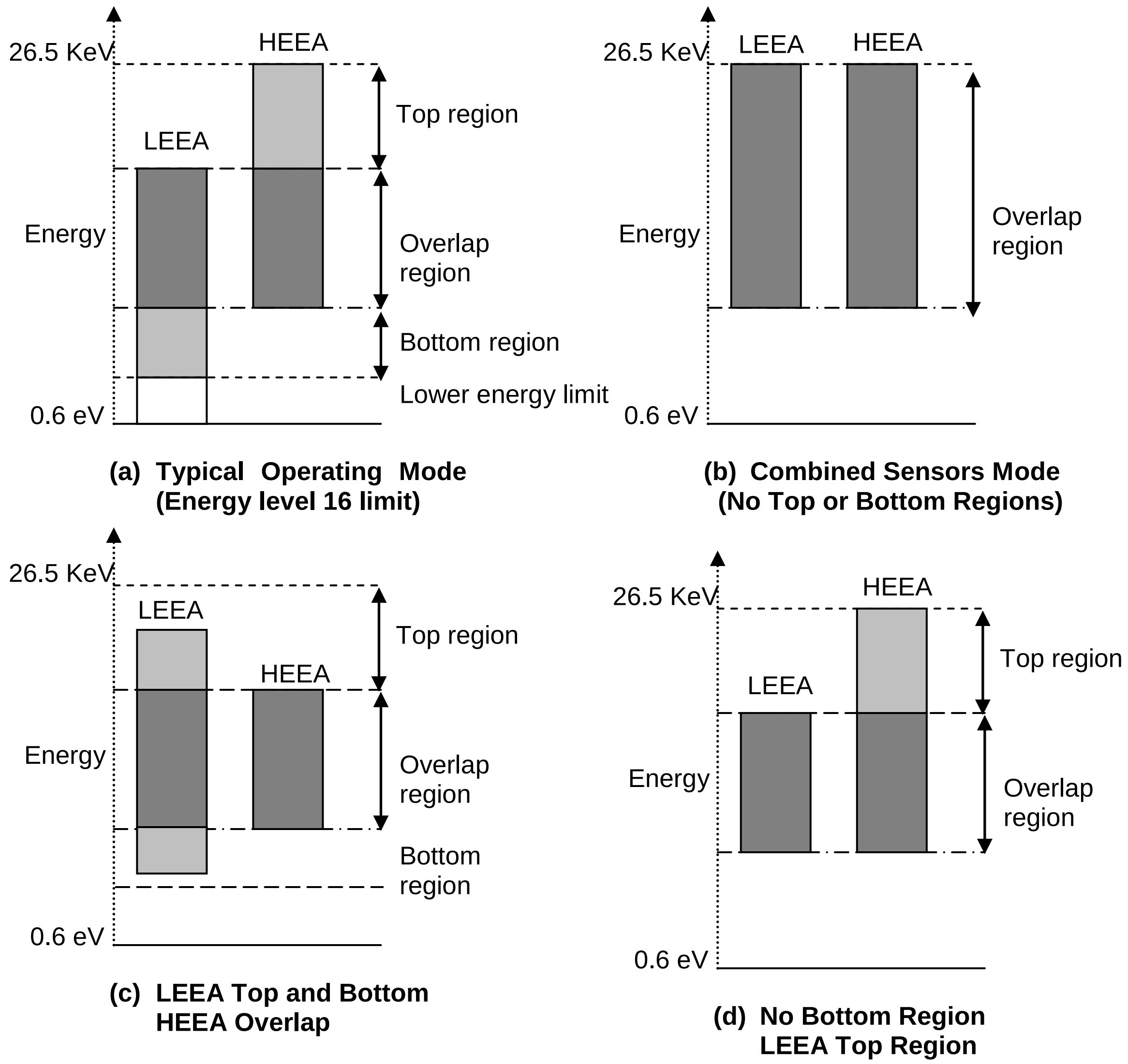


Figure 5. Illustration of possible sensor energy range coverage, and corresponding definition of moment sums regions for onboard calculations

3.5.3 Diagnostic Data Products

3.5.3.1 LER Low Energy Reduced 3-D Distribution

The LER data product contains data from only one sensor, usually LEEA.

LER is essentially a heavily reduced 3-D distribution. Only a restricted subset of data collected during a single satellite spin is included, specifically the lowest 16 levels of the energy table 9up to 9.5 eV). LER is intended for monitoring the interaction between the spacecraft and the local plasma environment.

LER data is usually sent routinely in both Normal Mode and Burst Mode spacecraft telemetry operations. On spacecraft 2, after 25 November 2001, it is sent less frequently in order to ensure that 3DR can be sent as close to every spin as possible.

The total number of values per spin is 192, distributed among energy, polar and azimuths as follows (depending on sweep mode);

LAR	16e x 3p x 4a x 1s
MAR	8e x 3p x 8a x 1s
HAR	8e x 3p x 8a x 1s

This is achieved onboard in slightly different ways for each sweep mode. In all sweep modes, polar angle resolution is reduced by a factor 4, by adding data from 4 neighbouring polar zones (i.e. 0,1,2,3; 4,5,6,7; 8,9,10,11). Energy and azimuth are handled as follows:

LAR:

(i) Reduce azimuth angle coverage (but not resolution) by including only 4 of a possible 16 azimuths in a given spin, cycling through several spins to get complete azimuthal coverage (i.e., spin 0, azimuths 0, 4, 8, 12; spin 1, azimuths 1, 5, 9, 13; etc to spin 4, azimuths 3, 7, 11, 15)

(ii) No energy resolution reduction; energy range is only the lowest 16 bins in the sweep.

MAR:

(i) Reduce azimuth angle coverage (but not resolution) by including only 8 of a possible 32 azimuths in a given spin, cycling through several spins to get complete azimuthal coverage (i.e., spin 0, azimuths 0, 4, 8, 12, 16, 20, 24, 28; spin 2, azimuths 1, 5, 9, 13, 17, 21, 25, 29; etc to spin 4, azimuths 3, 7, 11, 15, 19, 23, 27, 31)

(ii) No energy resolution reduction; energy range is only the lowest 8 bins in the sweep.

HAR:

(i) Reduce azimuth angle coverage (but not resolution) by including only 8 of a possible 64 azimuths in a given spin, cycling through several spins to get complete azimuthal coverage (i.e., spin 0, azimuths 0, 8, 16, 24, 32, 40, 48, 56; spin 2, azimuths 1, 9, 17, 25, 33, 41, 49, 57; etc to spin 8, azimuths 7,15, 23, 31, 39, 47, 55, 63)

(ii) No energy resolution reduction; energy range is only the lowest 8 bins in the sweep.

Thus, full 4π solid angle coverage can be achieved by combining data from 4 consecutive spins in LAR and MAR or 8 consecutive spins in HAR.

The error range associated with compression/decompression for transmission is, at worst, $\pm$ 3%.

3.5.3.2 NOI

The NOI data product always contains both HEEA and LEEA data (LEEA appear first).

NOI data is only generated during MCP Operational level tests, which generally occur once a week, during Normal Mode spacecraft telemetry operations.

All measured values collected during a single satellite spin are included.

The total number of measured values per spin is 512, in which all energy bins are summed together, and azimuth bin data are also summed as per 3DR to provide 16 equal NOI azimuth sectors.

LAR/MAR/HAR 1e x 16p x 16a x 2s

The NOI data product is used during routine MCP operational level tests, and not as a Scientific data product. Only CAA users who wish to verify PEACE gain estimates will find it useful.

3.6 Instrument Data Products : Generated on the Ground

3.6.1 Moments Data

3.6.1.1 PP CSDS Prime Parameter Moments Data

The Cluster Science Data System "Prime Parameter" data (called "preliminary electron parameters" in CAA) for PEACE are spin resolution moments data derived from the "onboard moment sums" (OMS). They are not intended for publication.

The process of producing these data from OMS has several stages:
- (i) select the sensor from which to take data in the "overlap" region
- (ii) apply geometric factor corrections, including correction for time varying sensor sensitivity in all 8 sensors
- (iii) utilisation of the PP magnetometer data to derive $T_{\perp}$, $T_{||}$ and $Q_{||}$.
- (iv) utilisation of the PP EFW potential data to exclude energy bands and sometimes all data where contamination by photo-electrons is expected

However, these data are not always the best available moments data since
- (i) they do NOT use the most detailed or up-to-date calibration data (especially the energy efficiencies, affecting for example bulk velocity),
- (ii) there is no possibility of correcting the measured energies to account for the effects of acceleration by the spacecraft potential
- (iii) there is a possibility of inaccuracies associated with photoelectrons being treated as plasma electrons, although generally the time intervals where this is a risk are removed from the time series
- (iv) these data may in some situations represent only partial moments, i.e. applicable only for a subset of the measured energy range.

The accuracy of these moments thus may vary according to the calibration status and the plasma environment at the time of the observation.

The user is recommended to treat these data as indicative rather than definitive, and to refer to the MOMENTS data product for the best available moments data.

3.6.1.2 MOMENTS Moments Data

The initial release of these data will be generated automatically, but should be followed by a more carefully produced and checked dataset.

The dataset will include moments generated using 3D distributions (3DR, 3DX) as the source data
- (i) enabling the application of the best available calibrations
- (ii) enabling effective corrections for spacecraft potential
- (iii) enabling effective removal of spacecraft electrons

In some situations the best available moments may be the PP data, in which case they couldl be incorporated in MOMENTS. This has not been done as yet.

It is intended that this will be the CAA users main source of PEACE moments data.

3.6.2 Distribution Data

3.6.2.1 SPINPAD Pitch Angle Data

The PEACE IDFS SPINPAD product is assembled from PAD data to give a 13 element pitch angle product, each element covering 15° pitch angle sectors, with one such element capturing each of the field parallel and anti-parallel direction. No correction of possibly imperfectly selected pitch angles is attempted. These data are not delivered to the CAA.

3.6.2.2 3DFXR 3DR data from 3DX and 3DF

The PEACE IDFS 3DFXR data product is 3DR data has been generated during ground data processing from 3DX and 3DF distributions. This ensures a continuously available 3DR dataset throughout the mission, subject only to variable rate of transmission and gaps during instrument “off” period and MCP tests.

Note that when a reduced energy coverage form of 3DX is available, the 3DR produced from it naturally has a correspondingly reduced energy coverage.

3.7 CAA PEACE Data Products

3.7.1 Products Recommended for the General User

3.7.1.1 MOMENTS Moments Data

The initial release of these data will be generated automatically, but should be followed by a more carefully produced and checked dataset.

The dataset will include moments generated using 3D distributions (3DR, 3DX) as the source data
- (iv) enabling the application of the best available calibrations
- (v) enabling effective corrections for spacecraft potential
- (vi) enabling effective removal of spacecraft electrons

It is intended that this will be the CAA users main source of PEACE moments data.

3.7.1.2 PITCH_SPIN Rebinned Pitch Angle Data (Spin resolution)

The PITCH_SPIN data product contains spin resolution data in a 2-D energy vs. pitch angle array. The pitch angle data is derived from IDFS PAD data, but has been rebinned using accurate ground calibrated magnetometer to ensure a true representation of the measured pitch angles. It combines data from HEEA and LEEA in a single data array. Since it is based on PAD data it is expected to be available every spin.

3.7.1.3 3DR Standard Reduced Resolution 3-D Distribution

The CAA 3DR data products contain PEACE 3DR data and PEACE 3DFXR data. The data products are divided into 3DR-H from the HEEA sensor and 3DR-L from the LEEA sensor. These data products are commonly available.

The data product is used when the sensor sweep mode is any of HAR, LAR or MAR mode.

The data product is available whenever PEACE returned 3DR data. Note that in some situations 3DR data is transmitted from one sensor but not the other sensor.

3.7.2 Other Three Dimensional (3-D) Distributions Data

3.7.2.1 3DX, 3DXLAR Best Resolution 3-D Distribution

The CAA 3DX and 3DXLAR data products contain full resolution 3-D data from either PEACE 3DF data or PEACE 3DX, or reduced resolution 3-D data from PEACE 3DXE data. These data products are available relatively infrequently.

The 3DX and 3DXE data products are used when the sensor sweep mode is HAR or MAR mode, and 3DXLAR is used when the sensor is in LAR mode, which is relatively rare. The use of a separate data product for LAR mode is intended to allow for more efficient data file sizes.

The data product is available whenever PEACE returned 3DX, 3DXE or 3DF data. Note that 3DF data is transmitted from both sensors and only every few spins, whereas 3DX is usually available every spin but only from one sensor at any given time. 3DXE can in some cases be available from both sensors each spin but is usually available only from one sensor.

3.7.2.2 3DXP, 3DXPLAR Enhanced Resolution 3-D Distribution

The CAA 3DXP and 3DXPLAR data products contain reduced resolution 3-D data from PEACE 3DXP data. The 3DXP data product is commonly available during spacecraft Burst Mode telemetry.

The 3DXP data product is used when the sensor sweep mode is HAR or MAR mode, and 3DXPLAR is used when the sensor is in LAR mode, which is relatively rare. The use of a separate data product for LAR mode is intended to allow for more efficient data file sizes.

The data product is available whenever PEACE returned 3DXP data. Note that 3DXP is usually available every spin but only from one sensor at any given time. On spacecraft 1 and 3, 3DXP is typically available, only with reduced energy coverage.

3.7.2.3 3DXPA, 3DXPALAR 3DX Pitch Angle Distribution

The CAA 3DXPA and 3DXPALAR data products contain 3-D data from PEACE 3DXPA data, which consists of a subset of the 3DX distribution containing only the azimuth sectors which contain the magnetic field direction derived from onboard magnetic field data. The 3DXPA data product is commonly available during spacecraft Burst Mode telemetry.

The 3DXPA data product is used when the sensor sweep mode is HAR or MAR mode, and 3DXPALAR is used when the sensor is in LAR mode, which is relatively rare. The use of a separate data product for LAR mode is intended to allow for more efficient data file sizes.

The data product is available whenever PEACE returned 3DXPA data. Note that 3DXPA is usually available every spin but only from one sensor at any given time.

3.7.3 Other Pitch Angle Data Products

3.7.3.1 PITCH_FULL Rebinned Pitch Angle Data (PAD, Sub-Spin Res.)

PITCH_FULL, like PITCH_SPIN, is derived from PAD data, and the pitch angle data is again rebinned using accurate ground calibrated magnetometer to ensure a true representation of the measured pitch angles. Unlike PITCH_SPIN, the PITCH_FULL dataset keeps HEEA and LEEA in separate data arrays, which allows determination of sub-spin timing. This dataset offers a better chance of capturing un-aliased pitch angle distributions in rapidly changing plasmas than PITCH_SPIN.

3.7.3.2 PITCH_3D* Rebinned Pitch Angle Data (3D, Sub-Spin Resolution)

An additional option for capturing pitch angle data at sub-spin resolution is to use 3D data in which the energy-pitch angle array is provided for each energy sweep (= azimuth sector). This provides information during azimuth sectors that are not returned in PAD data. In a situation with rapidly

changing magnetic field, these azimuth sectors may capture useful information from a larger range of pitch angles than would be expected in a stable magnetic field situation. Such data can be generated for any 3D data product.
PITCH_3DXP(LAR) is currently incorporated into PITCH_3DX(LAR) data product. This will be reviewed in the future.

3.7.4 Ancillary Data Products

3.7.4.1 PAD Onboard Selected Pitch Angle Distributions

The CAA PADHAR, PADLAR and PADMAR data products contain PEACE PAD data. The data products are divided into -H from the HEEA sensor and -L from the LEEA sensor.

The PADHAR or PADLAR or PADMAR data products are used when the sensor sweep mode is HAR or LAR or MAR mode, respectively. The use of separate data products for each sweep mode is intended to allow for more efficient data file sizes.

These data products are commonly available, but are not the recommended way to access PEACE pitch angle data.

3.7.4.2 OMS Onboard Moment Sums

The CAA OMSH (HEEA) and OMSL (LEEA) data products contain PEACE onboard moments sums data, for both sensors and for any of the sweep modes LAR, HAR and MAR.

These data products are commonly available, but are not the recommended way to access PEACE moments data.

3.7.4.3 LER Low Energy Reduced 3-D Distribution

The CAA LER data product contains PEACE LER data, for the relevant sensor and for any of the sweep modes LAR, HAR and MAR.

3.7.4.4 NOI

See section 3.5.3.2

3.7.4.5 PP CSDS Prime Parameter Moments Data

See section 3.6.1.1

3.7.4.6 CAVEATS

Daily Caveat files are discussed in Appendix d of the User Guide. They are intended to provide an indication of when known problems occurred leading to bad data or missing data, and supplement detailed Status Flags within the Data files.

4 DATA PROVISION – GENERAL CONVENTIONS

4.1 Formats

The PEACE Team provides unrestricted access to the PEACE Database held at MSSL to the CAA, which contains Level 1 PEACE data and PEACE Calibration files. These may be copied locally at will by the CAA when required. The Database uses files which conform to the IDFS standard.

PEACE Level 1 data is stored as IDFS data and header files which are binary in format and whose filenames end in the letters “D” and “H” respectively.

Information required to generate Level 2 data (decompressed and in scientific units) is held in IDFS VIDF files. There are two current formats of VIDF files in use, version 2 and version 3. Version 2 VIDF files are available as human readable ASCII files whose filenames end with a letter “V”, and which are converted to binary files (same filename but now end with a letter “I”) when used by IDFS data processing software. Version 3 VIDF files are also available (filenames end with the letters ”V.v3”) and use an ASCII format that is both readable by humans and the IDFS data processing software. Additional supporting information required to export data from the database is available in ASCII format PIDF files (filename ends with the string “.pidf.v2” for version 2 format PIDFs).

The PEACE Team provides database export software to CAA. The export software produces data files conforming to the current Cluster Exchange Format (CEF-2) standard and the Cluster Metadata Dictionary, with data organised within them according to the detailed descriptions of Section 5.

All PEACE documentation will be submitted as PDF files.

4.2 Standards

Cluster Exchange Format - 2	DS-QMW-TN-0010	ver 2.0.3	21 September 2004
Cluster Metadata Dictionary	CAA-CDPP-TN-0002	ver 2.0	17 March 2005
IDFS (Instrument Data File Set)	IDFS Definition	ver 2.1 H	23 March 2004

The IDFS file format is described at: http://www.idfs.org

4.3 Production Procedures

The PEACE Team provides full access to the PEACE Database to the CAA, together with database export software. CAA will use this to generate data in scientific units as CEF-2 files from the PEACE Database. The CEF-2 files will be the archival product retrieved by the end user.

The provided export software will automatically promote any required IDFS files from the MSSL PEACE database to the local CAA machine and produce the specified CEF-2 files. The CAA may optionally promote the IDFS data before the CEF file production.

The PEACE Team will provide any CEF include files that are required for PEACE CEF headers generated by the database export software.

4.3.1 Summary of calibration process

The CEF-2 files produced using the export software provided by PEACE will contain data which is provided in calibrated format, with no separate calibration files.

The application of the IDFS calibration files to the IDFS raw data and generation of data in scientific units is all handled within the export software PEACE provides to the CAA.

4.3.2 Calibration file format

Calibration information is provided in the IDFS VIDF files. The general format guidelines are defined in the IDFS standard. The detailed implementation varies according to the data product.

4.3.3 PEACE electron data file format

PEACE Level 1 electron data is provided in the IDFS D and H files.
PEACE Level 2 electron data is provided as CEF-2 data files as described in detail in Section 5.
PEACE Level 3 electron data is provided as CEF-2 data files as described in detail in Section 5.

4.4 Quality Control Procedures

Yet to be defined in detail. A number of issues arise – handling of data gaps, corrupt data, producing moments without incorporating photoelectrons, tracking calibration versions in use.
All data products are checked for known errors with in-house validation software, for corrupt data with CEFpass routine provided by the CAA, and also for data gaps (daily gap intervals only). Problem files are fixed prior to delivery. A number of issues remains – producing moments without incorporating photoelectrons, tracking calibration version in use, etc.

4.5 Delivery Procedures

The PEACE team will advise the CAA to regenerate CEF files if/when revised calibrations are made available.

Similarly, the PEACE team will advise CAA when new IDFS data files or new/revised VIDF files are available at the MSSL PEACE IDFS database. New or revised CEF files should then be produced by the CAA.

5 DATA PROVISION – SPECIFIC DESCRIPTIONS

5.1 Level 1 Data – IDFS

These files have not been delivered to the CAA

5.1.1 Format:

Binary. See 4.1

5.1.2 Standard: IDFS (Instrument Date File Set)

See 4.2

5.1.3 Production Procedure:

These data files are not produced at the CAA.

5.1.4 Quality Control Procedure:

See section 4.4

5.1.5 Delivery Procedure:

See section 4.5

5.1.6 Product Specification

The IDFS data set for use at CAA will include:

- (i) All "raw" PEACE Telemetry, extracted from the Spacecraft Telemetry Stream, with timings applied and with PEACE data reassembled from subsets spread amongst ESOC TM packets. Specific data sets relevant to CAA include 3DF, 3DX, 3DR, LER, PAD, NOI.
- (ii) The ground produced IDFS dataset 3DFXR is also required for the 3DR product.
- (iii) Reorganised Pitch Angle Data "PITCH_SPIN, PITCH_FULL", details to be outlined in later release of the ICD
- (iv) Onboard moment sums derived from "OMS" in the "Core" data
- (v) Moments data set(s), details to be outlined in later release of the ICD
- (vi) Support data sets, such as CFUNIT magnetic field data used for ground-software pitch angle generation

5.1.7 Metadata Specification

N/A

5.2 Level 2 Data – Calibrated Onboard Products

5.2.1 Format: CEF

5.2.2 Standard:

File Format:	CEF-2.0 (See section 4.2)	
Time standard:	CSDS ASCII time standard	
Coordinate systems:	SR2 (The despun SR co-ordinate system) The planned dedicated pitch angle data product will be in a magnetic field aligned co-ordinate system (Zone numbering of anodes refers to the MCP division into 12 anodes (0-11). The numbering scheme is with respect to the spacecraft coordinates as described in Figure 1, with the look direction of anode 0 in the negative X direction and anode 11 in positive X direction in Figure 1, where the X axis is the Spin axis.)	
Units for Electron Data:	Counts per accumulation	counts
	Phase Space Density	s^3/km^6
	Differential Energy Flux	keV/cm^2-s-str-keV
	Differential Number Flux	#/cm^2-s-str-keV

5.2.3 Production Procedure:

The database export software provided to the CAA by PEACE generates the required CEF files directly from the pre-generated IDFS datasets. (See section 4.3)

5.2.4 Quality Control Procedure:

See section 4.4.

5.2.5 Delivery Procedure:

See section 4.5.

5.2.6 Product Specification

Specification includes spacecraft number, data product type, sensor, units, time and version number.

Cx_CP_PEA_3DX#_*__yyyymmdd_Vnn.cef
Cx_CP_PEA_3DXLAR#_*__yyyymmdd_Vnn.cef
Cx_CP_PEA_3DXP#_*__yyyymmdd_Vnn.cef
Cx_CP_PEA_3DXPLAR#_*__yyyymmdd_Vnn.cef
Cx_CP_PEA_3DXPA#_*___yyyymmdd_Vnn.cef
Cx_CP_PEA_3DXPALAR#_*__yyyymmdd_Vnn.cef
Cx_CP_PEA_3DR#_*__yyyymmdd_Vnn.cef
Cx_CP_PEA_PITCH_SPIN_*_yyyymmdd_Vnn.cef
Cx_CP_PEA_PITCH_FULL_*_yyyymmdd_Vnn.cef
Cx_CP_PEA_PITCH_FULL_LAR_*_yyyymmdd_Vnn.cef
Cx_CP_PEA_PITCH_3DX#_*__yyyymmdd_Vnn.cef
Cx_CP_PEA_PITCH_3DXLAR#_*__yyyymmdd_Vnn.cef
Cx_CP_PEA_PITCH_3DXPA#_*___yyyymmdd_Vnn.cef
Cx_CP_PEA_PITCH_3DXPALAR#_*__yyyymmdd_Vnn.cef
Cx_CP_PEA_PITCH_3DR#_*_yyyymmdd_Vnn.cef
Cx_CP_PEA_MOMENTS__yyyymmdd_Vnn.cef Note: no units are given in the filename
Cx_CP_PEA_LER#_*__yyyymmdd_Vnn.cef
Cx_CP_PEA_NOI#_cnts__yyyymmdd_Vnn.cef Note: only units of cnts
Cx_CP_PEA_PADLAR#_*__yyyymmdd_Vnn.cef
Cx_CP_PEA_PADMAR#_*__yyyymmdd_Vnn.cef
Cx_CP_PEA_PADHAR#_*__yyyymmdd_Vnn.cef
Cx_CP_PEA_OMS#__yyyymmdd_Vnn.cef Note: no units are given in the filename

Where: Cx refers to the spacecraft number (C1, C2, C3 or C4),
CP refers to the file containing a CAA Parameter
PEA refers to PEACE
3DR#, 3DX#, LER#, NOI#, PADMAR#, etc., refers to the data product type
and where # refers to either the LEEA sensor (L) or HEEA sensor (H).
* refers to the units the data is in and may be cnts, DEFlux, DNflux or PSD, these are units of counts per accumulation, differential energy flux, differential number flux and phase space density respectively.
yyyymmdd refers to year, month and day of the data in the file.
Vnn refers to the version number where nn is a two digit figure.

i.e. a full file name may be C4_CP_PEA_3DRL_DNFlux__20010701_V01.cef

Since LAR mode is so rarely used it was decided to separate out LAR mode data in to their own files in order to allow a more compact format for MAR and HAR data file with less fill values.

(Further products will appear in later versions of the ICD. See section 5.1.6 for details of IDFS data yet to be converted into CAA products.)

CEF header "include" files utilised by PEACE will have a similar naming convention. They will all be provided by PEACE unless otherwise stated.

Cx_CH_PEA_{product}#_{units}.ceh
CL_CH_MISSION.ceh
Cx_CH_OBS.ceh
CL_CH_PEA_EXP.ceh
Cx_CH_PEA_#EEA_INST.ceh
Cx_CH_PEA_{product}#_DATASET.ceh
Cx_CH_PEA_{product}#_{units}_PARA.ceh & special case: Cx_CH_PEA_OMS#_PARA.ceh
CL_CH_PEA_FILE.ceh

Where: {product} refers to 3DR, etc. as listed in the previous section
CH refers to the file containing a CAA Header file for CEFs
{units} refer to cnts, etc. as listed in the previous section
and x and # have the same meanings as above

CL_CH_MISSION.ceh and *Cx_CH_OBS.ceh* are header files provided by the CAA.

Note that 3D distributions are per sensor so always require an # (H or L) in their names and the same data is exported several times in different units, hence the requirement for {units} in the CEF header file names.

5.2.7 Metadata Specification

5.2.7.1 Mission

This file "CL_CH_MISSION.ceh" is provided and maintained by the CAA team at ESTEC. Its full extent can be found in section 6.1.

5.2.7.2 Observatory

There are four files called "C{I}_CH_OBS.ceh" where {i}=1-4. They are provided and maintained by the CAA team at ESTEC. The full extent of "C2_CH_OBS.ceh" can be found in section 6.2. Similar files exist for the other three spacecraft.

5.2.7.3 Experiment

The metadata related to PEACE was provided by the PEACE team in the include file "CL_CH_PEA_EXP.ceh" as follows

```
START_META = EXPERIMENT
   ENTRY    = "PEACE"
END_META    = EXPERIMENT
!
START_META = EXPERIMENT_DESCRIPTION
   ENTRY    = "The Plasma Electron And Current Experiment (PEACE) instrument
is designed to measure"
   ENTRY    = "the electron velocity distribution in the vicinity of its
host spacecraft, covering"
   ENTRY    = "an energy range of ~1 eV to ~26 keV and detecting electrons
arriving from all possible"
   ENTRY    = "directions. Each PEACE instrument has two sensor heads, LEEA
and HEEA, which are"
   ENTRY    = "mounted on opposite sides of the spacecraft such that the
instantaneous field of view"
   ENTRY    = "of one is the same as that seen by the other half a
spacecraft rotation period later."
   ENTRY    = "LEEA and HEEA differ only in geometric factor (HEEA admits
more electrons than LEEA"
   ENTRY    = "when measuring the same energy range). Both sensors sample
4*pi steradians per spin."
END_META    = EXPERIMENT_DESCRIPTION
!
! make this following one a pointer later
```

```
START_META = INVESTIGATOR_COORDINATES
   ENTRY    = "Andrew Fazakerley>anf@mssl.ucl.ac.uk>Principal Investigator"
END_META    = INVESTIGATOR_COORDINATES
!
START_META = EXPERIMENT_REFERENCES
   ENTRY    = "*CL_CD_PEA_CAAICD"
   ENTRY    = "*CL_CD_PEA_USERMAN"
   ENTRY    = "http://www.mssl.ucl.ac.uk/www_plasma/missions/cluster/"
END_META    = EXPERIMENT_REFERENCES
!
START_META = EXPERIMENT_KEY_PERSONNEL
   ENTRY    = "Andrew Fazakerley>anf@mssl.ucl.ac.uk>Principal Investigator"
END_META    = EXPERIMENT_KEY_PERSONNEL
!
START_META = EXPERIMENT_CAVEATS
   ENTRY    = "*CL_CQ_PEA_CAVEATS"
END_META    = EXPERIMENT_CAVEATS
```

All instances of a ↵ are indications of where a line has been split up in this document to multiple lines for readability, however the actually CEH file has a single line (with no ↵ symbols).

5.2.7.4 Instrument

The metadata related to PEACE on Cluster 1 was provided by the PEACE team in the include file “C1_CH_PEA_INS.ceh” as follows

```
START_META = INSTRUMENT_NAME
   ENTRY    = "PEACE1"
END_META    = INSTRUMENT_NAME
!
START_META = INSTRUMENT_DESCRIPTION
   ENTRY    = "The HEEA sensor of PEACE on Cluster C1."
   ENTRY    = "The full energy range is divided into 88 levels, however ↵
              only a subset (60 or 30)"
   ENTRY    = "of those can be sampled by each sensor in a given spin. ↵
              Full coverage of the"
   ENTRY    = "energy range may be achieved by using both HEEA and LEEA ↵
              sensors together, each"
   ENTRY    = "sampling a different (possibly overlapping) subset of the ↵
              energy range."
   ENTRY    = "HEEA will normally cover the upper part of the energy ↵
              range, since its larger"
   ENTRY    = "geometric factor enables it to make better measurements of ↵
              the more diffuse"
   ENTRY    = "electron population expected at higher energies."
END_META    = INSTRUMENT_DESCRIPTION
!
START_META = INSTRUMENT_TYPE
   ENTRY    = "Micro-channel_Plate"
   ENTRY    = "Electrostatic_Analyser"
END_META    = INSTRUMENT_TYPE
!
START_META = MEASUREMENT_TYPE
   ENTRY    = "Thermal_Plasma"
END_META    = MEASUREMENT_TYPE
!
```

```
START_META = INSTRUMENT_CAVEATS
   ENTRY    = "*C1_CQ_PEA_CAVEATS"
END_META    = INSTRUMENT_CAVEATS
```

All instances of a ↵ are indications of where a line has been split up in this document to multiple lines for readability, however the actually CEF file has a single line (with no ↵ symbols).

The INSTRUMENT_NAME, INSTRUMENT_DESCRIPTION and INSTRUMENT_CAVEATS metadata entries for PEACE2, PEACE3 and PEACE4 on Cluster 2, 3 and 4 are the same for PEACE1, but with the appropriate spacecraft number. INSTRUMENT_DESCRIPTION contains information on whether the data is from the HEEA or LEEA sensor.

The INSTRUMENT_DESCRIPTION for LEEA is the same as for HEEA, except the last three lines (in blue) above are replaced by the following:

```
   ENTRY    = "LEEA is designed to specialise in the coverage of the ↵
               lowest electron energies"
   ENTRY    = "(including below 10 eV) but is also capable of covering ↵
               the full energy range to"
   ENTRY    = "26 keV.  The LEEA sensor has a smaller geometric factor ↵
               appropriate for the"
   ENTRY    = "higher fluxes of electrons usually found at lower ↵
               energies, though LEEA does not"
   ENTRY    = "always sample the lowest energies."
```

The INSTRUMENT_DESCRIPTION for PEACE products that contain both HEEA and LEEA data is the same as for HEEA with the LEEA text above appended to it.

This is provided by PEACE in 8 include files of the form "Cx_CH_PEA_#EEA_INST.ceh", where x is 1-4 and # is H or L and 4 include files of the form "Cx_CH_PEA_HL_INST.ceh" (See section 5.2.6).

5.2.7.5 Dataset

The following example is for a 3DR product of spacecraft 1's PEACE HEEA sensor:

```
START_META = DATASET_ID
   ENTRY    = "C1_CP_PEA_3DRH_cnts"
END_META    = DATASET_ID
!
START_META = DATASET_TITLE
   ENTRY    = "PEACE 3DRH data from the HEEA sensor"
END_META    = DATASET_TITLE
!
START_META = DATA_TYPE
   ENTRY    = "CP>CAA Parameter"
END_META    = DATA_TYPE
!
START_META = DATASET_DESCRIPTION
   ENTRY    = "This dataset contains reduced resolution three dimensional ↵
               electron distributions"
   ENTRY    = "(3DR) from the PEACE HEEA sensor on the Cluster C1 ↵
               spacecraft."
   ENTRY    = "This data product is reduced by a factor of 8 from the ↵
               full resolution 3DF product."
   ENTRY    = "For all energy sweep modes (LAR/MAR/HAR) the extent of the ↵
               data structure (including"
   ENTRY    = "flyback information) will always be 16 azimuths x 6 polar ↵
               angles x 16 energy bins."
```

```
   ENTRY    = ""
   ENTRY    = "For all energy sweep modes, the 12 polar anodes are summed ↵
              to make 6 anode-pairs."
   ENTRY    = "The remaining compression is achieved in the following way:"
   ENTRY    = "- LAR sums 4 energies to a bin and 1 (3DF) azimuth  to get ↵
              a single 3DR azimuth."
   ENTRY    = "- MAR sums 2 energies to a bin and 2 (3DF) azimuths to get ↵
              a single 3DR azimuth."
   ENTRY    = "- HAR does not sum energy bins but 4 (3DF) azimuths to get ↵
              a single 3DR azimuth."
   ENTRY    = ""
   ENTRY    = "The effective time resolution of the data is reduced due ↵
              to these summations."
END_META    = DATASET_DESCRIPTION
!
START_META = CONTACT_COORDINATES
   ENTRY    = "Andrew Fazakerley>anf@mssl.ucl.ac.uk>Principal Investigator"
END_META    = CONTACT_COORDINATES
!
!
! The following Time Resolutions are supposed to be a guide to the ↵
! nearest second i.e. they are not accurate! High time resolution means
! closely space data points.
!
START_META = TIME_RESOLUTION
   ENTRY    = 4
END_META    = TIME_RESOLUTION
!
START_META = MIN_TIME_RESOLUTION
   ENTRY    = 3600
END_META    = MIN_TIME_RESOLUTION
!
START_META = MAX_TIME_RESOLUTION
   ENTRY    = 4
END_META    = MAX_TIME_RESOLUTION
!
START_META = PROCESSING_LEVEL
   ENTRY    = "Calibrated"
END_META    = PROCESSING_LEVEL
!
START_META = ACKNOWLEDGEMENT
   ENTRY    = "Please acknowledge the PEACE instrument team"
   ENTRY    = "and ESA Cluster Active Archive"
   ENTRY    = "in any publication based upon use of this data."
END_META    = ACKNOWLEDGEMENT
!
START_META = DATASET_CAVEATS
   ENTRY    = "*C1_CQ_PEA_3DRH_cnts"
END_META    = DATASET_CAVEATS
```

The DATASET_TITLE, DATASET_DESCIPTION, TIME_RESOLUTION, MIN_TIME_RESOLUTION and MAX_TIME_RESOLUTION metadata entries are dependent on the data type and the DATASET_ID and DATASET_CAVEATS depend on the units and the data type. These entries will then change accordingly.

This is provided by PEACE in 360 include files of the form “Cx_CH_PEA_{product}#_DATASET.ceh”, where x is 1-4, {product} is the data product type (i.e. 3DR) and # is H or L, and 4 include files of the form “Cx_CH_PEA_{product}_DATASET.ceh”. (See section 5.2.6).

6 COMMON HEADER FILES

6.1 Mission

Metadata specification for the Cluster mission is provided in the include file "CL_CH_MISSION.ceh" as follows

```
! Header file: CL_CH_MISSION.ceh
!
! Mission Level Metadata
!
START_META = MISSION
    ENTRY  = "Cluster"
END_META   = MISSION

START_META      = MISSION_TIME_SPAN
    VALUE_TYPE = ISO_TIME_RANGE
    ENTRY      = 2000-08-16T12:39:00Z/2009-12-31T23:59:59Z
END_META        = MISSION_TIME_SPAN

START_META = MISSION_AGENCY
    ENTRY  = "ESA"
END_META   = MISSION_AGENCY

START_META = MISSION_DESCRIPTION
    ENTRY  = "The aim of the Cluster mission is to study small-scale
structures of the magnetosphere "
    ENTRY  = "and its environment in three dimensions. To achieve this,
Cluster is constituted of four "
    ENTRY  = "identical spacecraft that will flight in a tetrahedral
configuration. The separation distances "
    ENTRY  = "between the spacecraft will be varied between 600 km and 20
000 km, according to the "
    ENTRY  = "key scientific regions."
END_META   = MISSION_DESCRIPTION

START_META = MISSION_KEY_PERSONNEL
    ENTRY  = "Philippe Escoubet>Philippe.Escoubet@esa.int >Cluster Project
Scientist"
END_META   = MISSION_KEY_PERSONNEL

START_META = MISSION_REFERENCES
    ENTRY  = "The Cluster and Phoenix Missions>Cluster project and
instrument teams>Space Sci. Rev. 79, Nos. 1-2, 1997"
END_META   =  MISSION_REFERENCES

START_META = MISSION_REGION
    ENTRY  = "Solar_Wind"
    ENTRY  = "Bow_Shock"
    ENTRY  = "Magnetosheath"
    ENTRY  = "Magnetopause"
    ENTRY  = "Magnetosphere"
    ENTRY  = "Magnetotail"
    ENTRY  = "Polar_Cap"
    ENTRY  = "Auroral_Region"
    ENTRY  = "Cusp"
```

```
    ENTRY    = "Radiation_Belt"
    ENTRY    = "Plasmasphere"
END_META     = MISSION_REGION

START_META = MISSION_CAVEATS
 ENTRY = "*CL"
END_META = MISSION_CAVEATS
```

6.2 Observatory

The metadata of the Cluster 2 observatory (for example) is provided in the include file "C2_CH_OBS.ceh" as follows

```
! Header file: C2_CH_OBS.ceh
!
! Observatory Level Metadata
!
START_META      =   OBSERVATORY
   ENTRY        =   "Cluster-2"
END_META        =   OBSERVATORY
!
START_META      =   OBSERVATORY_CAVEATS
   ENTRY        =   "*C2_CQ"
END_META        =   OBSERVATORY_CAVEATS
!
START_META      = OBSERVATORY_DESCRIPTION
   ENTRY        = "Cluster-2 (Salsa)"
   ENTRY        = "Launched: 16 Jul 2000"
   ENTRY        = "ESA Number: 2"
   ENTRY        = "COSPAR ID: 2000-041B"
   ENTRY        = "USSPACECOM catalogue number: 26411"
   ENTRY        = "CSDS Code: C2"
   ENTRY        = "ESOC FD code: S2"
   ENTRY        = "ESA Flight Model Number: FM6"
END_META        = OBSERVATORY_DESCRIPTION
!
START_META      = OBSERVATORY_TIME_SPAN
   VALUE_TYPE   = ISO_TIME_RANGE
   ENTRY        = 2000-07-16T12:39:00Z/2009-12-31T23:59:59Z
END_META        = OBSERVATORY_TIME_SPAN
!
START_META = OBSERVATORY_REGION
 ENTRY      = "Solar_Wind"
 ENTRY      = "Bow_Shock"
 ENTRY      = "Magnetosheath"
 ENTRY      = "Magnetopause"
 ENTRY      = "Magnetosphere"
 ENTRY      = "Magnetotail"
 ENTRY      = "Polar_Cap"
 ENTRY      = "Auroral_Region"
 ENTRY      = "Cusp"
 ENTRY      = "Radiation_Belt"
 ENTRY      = "Plasmasphere"
END_META    = OBSERVATORY_REGION
```

Similar files apply for the other three Cluster Spacecraft.

7 PEACE VARIABLES DESCRIPTION

The Parameter level is complicated due to the numerous different modes available. This has been simplified to make different products as consistent as possible in format, where each record covers one spacecraft spin.

7.1 Spin Record Variables

7.1.1 time_tags

This is the interval centred time tag for a PEACE spin. It is given as an ISO time.
The PEACE spin start time is found as: `time_tags – time_tags_DeltaLower`
The PEACE spin end time is found as: `time_tags + time_tags_DeltaUpper`
The upper and lower deltas are given in seconds.

7.1.2 Angle_SR2phi

This is the longitude (degrees) of the sensor on the spacecraft in the SR2 co-ordinate system at the precise moment of the centre time tag.

For HEEA it is calculated as follows:

```
Angle_SR2phi = (time_tags - TimeStamp_SunPulsePEACE)*360/SpinDuration +
                   + SPOS*360/(16*1024) - 30 - 26.2
```

Where `TimeStamp_SunPulsePEACE` is the time of the Sun Pulse as received by PEACE,
and `SpinDuration` = `time_tags_DeltaUpper + time_tags_DelataLower`
and `SPOS` is the PEACE Sun Pulse Off-Set, a variable that can be altered by the operations team.

`TimeStamp_SunPulsePEACE` and `SPOS` values are not provided separately in the product files, only the final value of `Angle_SR2phi`.

For LEEA, the result is simply 180 degrees away from that of HEEA:

```
Angle_SR2phi = (time_tags - TimeStamp_SunPulsePEACE)*360/SpinDuration +
                   + SPOS*360/(16*1024) - 30 - 26.2 - 180
```

There is no specific latitude variable in the SR2 co-ordinate system provided, but it could easily be worked out from the `Sweep_Polar` variable.

The main reason for including this variable was to allow sub-record timings of azimuth bins to be calculated, see Appendix C for further information.

7.1.3 Mode_SunpulseRephaseOffset

This quantity is a measure of the delay following the reception of a sun pulse from the spacecraft, by the PEACE Data Processing Unit, before the PEACE instrument commences a new cycle of activity. The delay or “rephase interval” is expressed in units of “spin segment clock pulses”. There are 16,384 SSCPs per spin; the duration of a SSCP is defined by the spacecraft. In essence the PEACE spin interval (rephased sunpulse to rephased sunpulse).is deliberately delayed with respect to the spacecraft spin interval (sunpulse to sunpulse). The (variable) delay provides a method to ensure that PEACE does not measure low energy electrons at the time when they are most likely to be contaminated with photoelectrons generated within the analyser, i.e. when the sensor aperture “looks” at the Sun. The value at the start of the mission was 176.

7.2 Sensor Setup Variables

7.2.1 Mode_Sensor

This specifies which sensor the data in the CEF file came from, LEEA, HEEA or both.

Value	*Description of original 3D distribution in IDFS*
0	HEEA sensor only
1	LEEA sensor only
2	Both LEEA and HEEA sensors are used (not applicable to 3-D products)

This variable is provided in the CEF header rather than the record for single sensor products as it will not change over time. Although many data products by definition contain only data from only one sensor, moments data and possible pitch angle data may be provided using dual sensor data.

7.2.2 Mode_SweepMode

This specifies which sweep mode the particular PEACE sensor is operating in at the time (see section 3.2.4, Azimuth Angle Coverage and Resolution) and can take a value from 0 to 3.

Value	*Description of Sweep Mode*
0	Sensor is switched off or is in Fixed mode
1	LAR – Low Angular Resolution
2	HAR – High Angular Resolution
3	MAR – Middle Angular Resolution

7.2.3 Mode_Preset

This is the parameter used to command the high voltage sweep generator energy range. (See section 3.2.3 Energy Coverage and Resolution.) It may be useful in some data analysis software.

7.2.4 Mode_EnergyLevelRange

This is the Sweep Energy Level range which is the subset of the 88 possible energy levels actually measured (not including flyback) specified as two values, a Start (high) and End (low). (See section 3.2.3 Energy Coverage and Resolution.) Common modes include a start of 88 and an end of 28, or a start of 72 and an end of 12, however there are many possibilities. These are expressed in units of PEACE levels rather than eV (see `Mode_EnergyMaxMin` for eV).

7.2.5 Mode_EnergyMaxMin

The energy range (in eV) of electrons measured for that spacecraft spin, expressed as two values; the Maximum and then the Minimum. This is `Mode_EnergyLevelRange` expressed in units of eV rather than levels.

7.2.6 Mode_MCPlevel

The MCP within each detector can have a voltage applied across it at one of 31 different levels (see section 3.2.8 Detectors). The gain of the sensor is uncontrolled by this applied voltage however as the sensor ages the gain at a given voltage will slowly decay. This can be countered by increasing the MCP level which will instantly increase the gain although the slow decay will continue. Sometimes the MCP level has been deliberated lowered in certain plasma regions to allow qualitative results rather than quantitative to be made. As such a researcher using the data should be aware if this value is changing during any period of scientific interest.

7.3 Dataset Origin Variable

7.3.1 Mode_DataOrigin

This variable is used to track the data within the record back to its parent IDFS data product. It can take a value from 0 to 22, although does not use all values in between.

Value	*Description of original 3D distribution in IDFS*
0	3DF
1	3DX1
2	3DX2
3	3DR
4	PAD
5	LER
6	NOI
7	Core
8	Housekeeping
9	Modes
11	3DXE1
12	3DXE2
21	3DXP1
22	3DXP2

The unit digit specified the onboard source distribution of the data, while the tens digit gives information on summing prior to the date being returned for the hi-resolution datasets; 0? for no summing, 1? for energy summation and 2? for polar summation.

For instance, the CAA product 3DX could have a `Mode_DataOrigin` value of 0, 1, 2, 11 or 12. Similarly the CAA product 3DR will mainly contain data from the onboard 3DR distribution (value 3) however we calculate a 3DR distribution on the ground from a high resolution product (values 0, 1, 2, 11, 12, 21 or 22) to populate gaps in time of the CAA 3DR product.

7.4 Dataset Description Variables (3D and PITCH products)

7.4.1 Mode_RealSize

This is an array of size 3 that contains the dimensions of the data as it comes off PEACE on the spacecraft per spin in terms of number of azimuths, number of polar bins and number of energy bins sampled respectively.

In the case of 3DXLAR, 3DXPLAR, 3DXPALAR, 3DR, PADLAR, PADMAR, PADHAR and NOI this is exactly the same as the `Data` variable's SIZE metadata entry. But this is not the case for the other products.

For the 3DX, 3DXP, 3DXPA and LER CAA products we find that the `Data` variable has approximately 50% of its elements as fill values. This is a function of the CEF format forcing us to specify a SIZE for the `Data` variable that is rigid in terms of the three dimensions, whereas PEACE takes data in such a way that the volume is constant but the three dimensions can vary for LAR, MAR or HAR modes. As such the `Data` variable's SIZE metadata must be that of the extremes of all dimensions.

For instance the measured 3D distribution (3DF) data has the following dimensions:
LAR mode: 16 azimuths by 12 polars by 64 energies (volume = 12288 elements)

MAR mode:	32 azimuths by 12 polars by 32 energies	(volume = 12288 elements)
HAR mode:	64 azimuths by 12 polars by 16 energies	(volume = 12288 elements)

Required size for CEF specification to handle all three modes:

CAA:	64 azimuths by 12 polars by 64 energies	(volume = 49152 elements)

The result requires us to pad out the energies and/or azimuths with fill values to reach the proper size, and now only 25% of the `Data` variable contains any real data. For this reason it was decided to split the rarely commanded LAR mode data out in to their own CAA parameter for the high resolution products such that we can reduce the extreme dimensions of the `Data` variable's SIZE for the far more common MAR and HAR modes.

Even so, the reduction to a SIZE of 64 azimuths by 12 polars by 32 energies still results in a file that has 50% fill values for IDFS 3DF data.

Continuing the example from the IDFS 3DF data, which will be part of the CAA 3DX product we will have the following situations:

3DF MAR mode:	`Data` variable SIZE = 64, 12, 32	Mode_RealSize data = 32, 12, 32
3DF HAR mode:	`Data` variable SIZE = 64, 12, 32	Mode_RealSize data = 64, 12, 16

It is always the initial array elements that contain the real data, so for the MAR mode case the first 32 azimuths have real data and the last 32 azimuths contain nothing but fill values. Similarly with HAR mode, all 64 azimuths contain data, but the energy sweep of each azimuth is populated with real data for the first half, and the second half are fill values.

Things can be more extreme, for instance the IDFS 3DX1E dataset sums the energies but is still part of the CAA 3DX product, such that:

3DX1 MAR mode:	`Data` variable SIZE = 64, 12, 32	Mode_RealSize data = 32, 12, 16

In this case the first 16 energies are always real and the second half always fill values, for the first 32 azimuths, then the final 32 azimuths are all fill.

Note, by real values we are referring to data that has come off the spacecraft which includes fly-back bins (see section 3.2.3) and windowed-out bins (see section 3.5.3) rather than padding fill-values to reach the maximum SIZE. However the fly-backs and windowed-out bins are also represented as fill-values and are as such indistinguishable from padding fill-values except by their indices in relation to `Mode_RealSize`. If you wish to know how many real elements you would expect to find per energy sweep not including fly-backs nor windowed out data use the `Mode_RealBinNum` variable.

7.4.2 Mode_RealBinNum

This is used in conjunction with `Mode_RealSize`, which allows you to pull out the subset of valid data from the padding fill values within the `Data` variable. However valid data can still contain fly-back bins and bins that have been windowed-out, both of which are represented by fill values.
`Mode_RealBinNum` gives you the number of energy bins (per azimuth sweep per polar zone) that contains real data that is neither a fly-back bin nor windowed-out. However, unlike `Mode_RealSize`, it does not give you any information on where in the array these values are. You may assume that all the real values are adjacent to each other, but they do not have to start at the zeroth index (they start at the first index that is not a fill value).

7.4.3 Sweep_Energy

`Sweep_Energy` is the representative Energy of any given individual PEACE measurement in eV. Representative energy is slightly different to centre energy in that the voltage decay of the hemispheres in the top hat analyser was measured and integrated between the lower and upper edges of the bin to find the average value.

It is the DEPEND_3 variable for the main `Data` variable.

The lower edge of the bin is found as:
`Sweep_Energy – Sweep_Energy_DeltaLower`
The upper edge of the bin is found as:
`Sweep_Energy + Sweep_Energy_DeltaUpper`

7.4.4 Sweep_Polar

`Sweep_Polar` is the centre polar angle of each anode (or anode-pair or anode-quad) on the sensor's MCP, measured in degrees where 0 degrees describes the +X spacecraft axis (the spin axis) and who's values lie between 0 and 180 degrees.

It is the DEPEND_2 variable for the main `Data` variable.

The lower edge of the bin is found as:
`Sweep_Polar – Sweep_Polar_DeltaLower`
The upper edge of the bin is found as:
`Sweep_Polar + Sweep_Polar_DeltaUpper`

To transform `Sweep_Polar` in to SR2 Latitude, use the following equation:
`SR2 Latitude = 90 degrees – Sweep_Polar`

(See `Angle_SR2phi` for SR2 Longitude.)

Since Sweep Polar is fixed to the spacecraft frame, the values do not change for the given dataset and as such their values are found in the CEF header rather than individual records.

7.4.5 Sweep_Azimuth

`Sweep_Azimuth` is the centre azimuthal angle of each voltage sweep of the hemispheres measured in the SR2 co-ordinate system. It is measured in degrees and can take values from 0 to 360 degrees.

It is the DEPEND_1 variable for the main `Data` variable.

The lower edge of the bin is found as:
`Sweep_Azimuth – Sweep_Azimuth_DeltaLower`
The upper edge of the bin is found as:
`Sweep_Azimuth + Sweep_Azimuth_DeltaUpper`

When calculating the edges the angles may fall below 0 or be greater than 360, in which case add or subtract 360 degrees as necessary.

7.4.6 Sweep_PitchAngle

`Sweep_PitchAngle` is the centre pitch angle for rebinned pitch angle data and the value lies between 0 and 180 degrees. There are 12 bins of 15° pitch angle width to cover the range.

It is the DEPEND_2 variable for the main `Data` variable.

The lower edge of the bin is found as:
`Sweep_PitchAngle – Sweep_PitchAngle _DeltaLower`
The upper edge of the bin is found as:
`Sweep_PitchAngle + Sweep_PitchAngle_DeltaUpper`

Since Sweep PitchAngle is fixed by definition, the values do not change and as such their values are found in the CEF header rather than individual records.

7.4.7 Data

This is the main data variable of the file and contains the 2-D or 3-D array (depending on the Dataset) of the measured electron distribution for a spin.

There will always be fill-values within this variable. Some will be fly-back fill-values or windowed-out fill-values, others will be padding fill values required to bulk up the array to an appropriate SIZE for the `Data` variable – see `Mode_RealSize` for a description. Unfortunately CEF permits only a single fill-value so we cannot distinguish the type of fill-value easily.

This variable is dependent on time and may be dependent on up to three other variables to describe each dimension; `Sweep_Azimuth`, `Sweep_Polar`, `Sweep_PitchAngle` and `Sweep_Energy`.

7.4.8 Background Level

This gives the background level for each measurement bin in the `Data` variable. It is set according to a typical value of 1/8 count per measurement.

Higher levels of counts which are not due to the plasma electrons are possible due to penetrating radiation (e.g. when the spacecraft is in the terrestrial radiation belts, or a Solar Energetic Particles event) and due to photoelectrons (possibly) seen when the sensor faces the Sun and secondary electrons (possibly) seen in high plasma flux environments. These are NOT represented in the current version of this parameter.

It is not included for the CAA NOI product as NOI is considered to be of use for operational tests only.

7.5 Dataset Description Variables (MOMENTS Data Product)

These are the best available moments data. Where possibly they are generated from 3D distributions, with corrections for spacecraft potential.

7.5.1 Mode_TopRegionSensor

This describes which sensor is used as the data source for the partial moments in the Top region of the distribution (see 3.5.2.2 for an explanation of partial moments "regions"). The definition of the parameter values, is the same as for Mode_Sensor (see 9.2.1).

7.5.2 Mode_OverlapRegionSensor

This describes which sensor is used as the data source for the partial moments in the Overlap region of the distribution (see 3.5.2.2 for an explanation of partial moments "regions"). The definition of the parameter values, is the same as for Mode_Sensor (see 9.2.1).

7.5.3 Mode_BottomRegionSensor

This describes which sensor is used as the data source for the partial moments in the Bottom region of the distribution (see 3.5.2.2 for an explanation of partial moments "regions"). The definition of the parameter values, is the same as for Mode_Sensor (see 9.2.1).

7.5.4 Data_Density

This is the electron density determined for the energy range sampled by the sensor or sensors. It may not correspond to the total plasma electron density, if there is a component of the electron plasma that PEACE did not measure.

7.5.5 Data_Velocity_GSE

This is the electron velocity vector in GSE coordinates, determined for the energy range sampled by the sensor or sensors. There are 3 components.

7.5.6 Data_Velocity_ComponentParallelToMagField

This is the component of the electron velocity vector parallel to the magnetic field direction, given in GSE coordinates. It is determined for the energy range sampled by the sensor or sensors. The magnetic field data source is usually the CSDS FGM PP data.

7.5.7 Data_Velocity_ComponentPerpendicularToMagField

This is the component of the electron velocity vector perpendicular to the magnetic field direction, given in GSE coordinates. It is determined for the energy range sampled by the sensor or sensors. The magnetic field data source is usually the CSDS FGM PP data.

7.5.8 Data_Pressure_GSE

This is the electron pressure tensor in GSE coordinates, determined for the energy range sampled by the sensor or sensors. There are 9 components.

7.5.9 Data_HeatFlux_GSE

This is the electron heat flux vector in GSE coordinates, determined for the energy range sampled by the sensor or sensors. There are 3 components.

7.5.10 Data_Temperature_ComponentParallelToMagField

This is the component of the electron velocity vector parallel to the magnetic field direction, given in GSE coordinates. It is determined for the energy range sampled by the sensor or sensors. The magnetic field data source is usually the CSDS FGM PP data.

7.5.11 Data_Temperature_ComponentPerpendicularToMagField

This is the component of the electron velocity vector perpendicular to the magnetic field direction, given in GSE coordinates. It is determined for the energy range sampled by the sensor or sensors. The magnetic field data source is usually the CSDS FGM PP data.

7.6 Variables specific to OMS Data Product

These are the onboard calculated moment sums as generated within the PEACE DPU. They are provided in instrument co-ordinates. The onboard moment sums have no corrections for non-zero spacecraft electrostatic potential. The accuracy is also affected by the use of calibration parameters stored onboard which may not always be perfect. Optimised versions of these data for scientific use are provided elsewhere in the CAA, for example as CSDS Prime Parameters.

The variable names will be described below. The asterisk stands for Top, OverlapFirstHalf, OverlapSecondHalf, or Bottom, for reasons that are explained in section 3.5.7.

Note that the Top or Bottom sections could contain data from either HEEA or LEEA. Where a sensor did not contribute to a Region, fill values populate that data file.

If the spacecraft is in single sensor operations then there is no overlap region and the Top region alone is populated, the other 5 regions are all set to fill values. Alternatively, if LEEA and HEEA are set up in such a way that there is no overlap in energy, only the Top and Bottom regions will be populated, with the 4 overlap regions all set to fill values.

7.6.1 Data_*_SummedCountRates

This is the total number of electrons counted in the specified region during the corresponding interval (which could be a full spin for Top or Bottom regions, otherwise it is half a spin).

7.6.2 Data_*_M1Sum

This is the summation used as the basis for density of electrons in the specified region during that interval (which could be full spin for Top or Bottom regions, otherwise half a spin). Onboard information about instrument calibrations are used in the calculation.

7.6.3 Data_*_M2Sum

As above, except that this is the basis for the Integral Number Flux

7.6.4 Data_*_M3Sum

As above, except that this is the basis for the Integral Pressure Flux

7.6.5 Data_*_M4Sum

As above, except that this is the basis for the Integral Heat Flux

7.6.6 Region_*_EnergyIntegration

This indicates the energy range over which the summations were performed for the relevant region. It is provided as two values, a maximum and minimum value, in units of eV..

7.7 Status Variables

7.7.1 Introduction

The Status variables are intended to provide additional data, at spin record level, that may affect the interpretation of the science data. They are complemented by daily Caveats files (see 3.7.4.6). Each status variable has the same format and consists of an array of 3 values.

The first element is the “Status Value”. This is the important parameter and its value has different meanings depending on what the status variable is for. A value of “-1” is a fill value. See the following sections for their explanations for each Status_* variable. While the variable names of the included status values have been decided upon, some of the status variables are populated by fill values in CEF files produced at the time of the release of this document. Work on fully describing each status variable continues and will be announced in a later document release.

The second element is the “Source of Status Value”, this is used to track where the information used to generate the “Status Value” came from. The parameter values are interpreted as follows

Value	*Source of Status Value*
-1	Fill Value
0	no data or turned off
1	data sourced from **on-board** data provided by relevant instrument team
2	data sourced from **ground** Calibration file provided by relevant instrument team

3 source from **CSDS JP** file
4 source from **CSDS SP** file of relevant instrument team
5 source from **CSDS PP** file of relevant instrument team
6 source from **CAA** file of relevant instrument team
7 data **inferred from PEACE** distributions
8 data sourced from the relevant instrument team

The third element is the "Version Number of Source of Status Value", for instance if the parameter came from a PP file, what version number was that PP file.

The full list of status values follows, where only the first element will be described in details.

7.7.2 Status_Quality

This is the Quality flag as defined by the CAA Metadata Dictionary. In PEACE files, it is intended to be set taking into account the state of other Status Flags. At the time of writing, the Flag is set to 1 in the case of Datastream Errors, Eclipse operations and to reflect the problem with an anode on Cluster 3 HEEA that broke on 22 August 2005 and Cluster 2 LEEA on 15 May 2011. The Flag is set to 2 during WHISPER active mode intervals. Otherwise the Flag is set to 3.

Status_Quality	Definition
0	Not applicable
1	Major problems, check caveats
2	Minor problems, check caveats
3	Good data
4	Excellent data, has received special treatment

7.7.3 Status_DatastreamErrors

Very occasionally there may be an error in the PEACE data stream. Illustrations are provided in the User Guide.

Status_Datastream Errors	Definition
0	No known data stream errors
1	PEACE sensor to DPU data transfer error (bit flip)
2	DPU re-sync for 16 spins

7.7.4 Status_Validation

This flag is intended for MOMENTS data files only. It states how the data have been generated and whether or not a human has validated that data (if not the reliability may possibly be lower than otherwise). Typically the flag is set to 0.

Status_Validation	Definition
0	automatically generated data; no validation
1	automatically generated data; reviewed by a human and accepted
2	generated by a human and accepted

7.7.5 Status_Eclipse

Indicates that PEACE was using an internal sunpulse; i.e. operating in an eclipse.
In such cases, 3D data may not perfectly represent 4π solid angle coverage and moments expressed in geophysical coordinates should be considered unreliable as the transformation from spacecraft to geophysical coordinates is expected to be incorrect. Pitch angle data will be unaffected, since neither the magnetic field nor the electron data need to be referred to a geophysical coordinate system to produce pitch angles. An illustration is provided in the User Guide.

Status_Eclipse	Definition
0	Normal operations
1	Eclipse mode

7.7.6 Status_ASPOC

These states whether ASPOC was on or off for any given record. When ASPOC is active, the spacecraft potential is typically reduced and less variable, usually improving the measurements of low energy electrons by PEACE. Note that ASPOC was never operated on spacecraft 1, and is not operated on any spacecraft after June 2008.

Status_ASPOC	Definition
0	ASPOC Off
1	ASPOC On

The source of this is the ASPOC PP file, therefore the second element of this variable = 5.
The version number is that of the PP file.

7.7.7 Status_FGM

The availability or otherwise of good quality FGM data for ground data processing is relevant to the provision of PEACE rebinned pitch angles and of moments in magnetic field aligned coordinates. Availability or otherwise of good quality FGM data to PEACE on the spacecraft is relevant to good onboard pitch angle selection, but this issue is handled with other Status parameters (see below).

Status_FGM	Definition
0	No problems with CAA FGM data
1	No CAA FGM data available
2	FGM On but bad data onboard due to FGM calibration runs
3	FGM On but bad data onboard due to FGM IEL problem

The source of item 1 is CAA FGM GAPF files.The source of items 2 and 3 is a list of known FGM in-flight calibration runs and intervals with IEL problems inferred from our IEL data.

7.7.8 Status_InterferenceFromEFW

EFW may cause interference in PEACE data during its bias sweeps.

Status_InterferenceFromEFW	Definition
0	No known interference from EFW
1	EFW sweeping during spin – possible interference

The source of this is the EFW PP file, therefore the second element of this variable = 5.
The version number is that of the PP file.

7.7.9 Status_InterferenceFromWHI

WHI may cause interference in PEACE data during its "active sounding" sweeps. An illustration is provided in the User Guide.

Status_InterferenceFromWHI	Definition
0	No known interference from WHISPER
1	WHI active sounding during spin – possible interference

The source of this is the WHISPER PULSE IDFS file, which is in turn produced from WHISPER housekeeping data (courtesy of software provided to the PEACE team by the WHISPER team) therefore the second element of this variable = 5.

7.7.10 Status_CountStats

This is a count rate statistics status variable designed (in the present incarnation) only for 3DR data and Moments data produced from 3DR data:

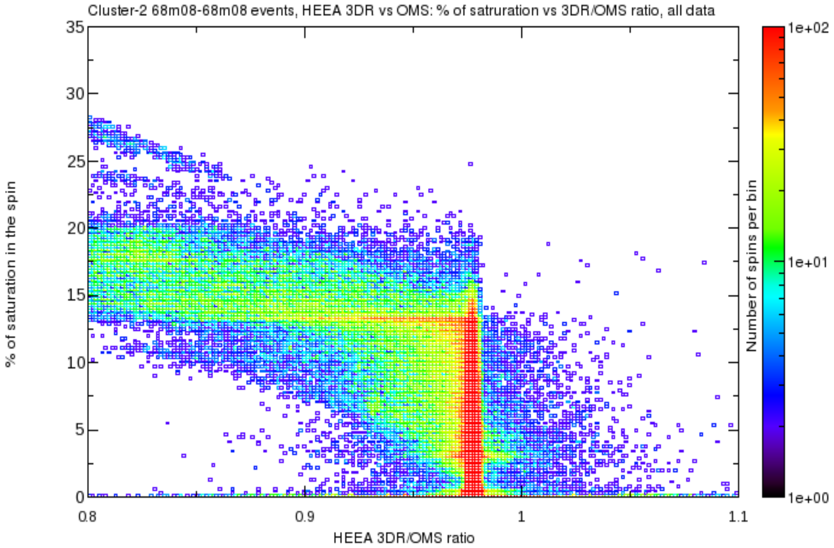
Status_CountStats	Definition
0	No problems
1	Caution: low average count rate in the distribution
2	Caution: possible underestimate of total counts in the distribution
3	Warning: definite underestimate of total counts in the distribution

If the average count rate in the distribution, after removal of photoelectrons (i.e. the energy bin containing the spacecraft potential and 2 bins above that) and after removal of 2 sun-facing azimuths, is below 1 count per 3DR bin (equivalent to 1/8 count per full resolution PEACE accumulation), the flag is set to 1.

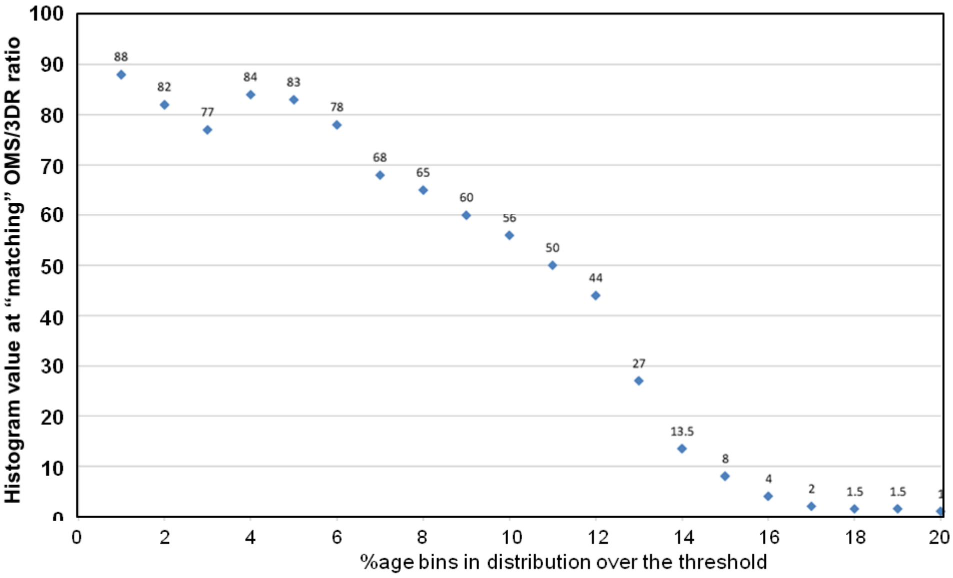
The high count rate "caution" and "warning" levels are set if the fraction of 3DR bins in a spin record (excluding photoelectrons) in which the count rate exceeds 7,920 is greater than 6% or 13% respectively. These thresholds have been empirically determined to distinguish between situations where a data compression artefact does not/may/does cause an under-reporting of the true count rates measured by the sensor. It is more likely that HEEA rather than LEEA will show such a problem.

Due to the design of the compression software used in the PEACE DPU, in the 3DR data product, values in excess of 15,840 may be reported as values between 7,920 and 15,840, so that it is not completely clear if values in that range are correct or not, and no values above 15,840 are returned.

In order to assess whether data values in 3DR distributions are likely to be affected, we have used comparisons of OMS total counts/spin available from the onboard moments software (not subject to the same data compression technique) and total counts/spin from the 3DR data to identify affected spins. In both cases, "total counts" refers to energy bins above energy level 16 (~10 eV). An example of the results is shown in the following figure.



In order to assess whether data values in 3DR distributions are likely to be affected, we have used comparisons of OMS total counts/spin available from the onboard moments software (not subject to the same data compression technique) and from the 3DR data to identify affected spins.



We have established that when > 13% of the data in a 3DR distribution have values > 7,920, there is better than a 90% probability that Moments based on the 3DR record will be incorrect. Similarly, once the %age of bins over the threshold exceeds 6%, the probability of producing reliable Moments falls, but is still of order 50% or less (see figure above).

Separate studies are still needed to assess whether limitations on MCP performance contribute to under-reporting of count rates in some environments. These will be carried out with data products in which fewer measured bins are added together than the 3DR case, as these are less affected by the data compression issue.

The source of the information is analysis of PEACE data, therefore the second element of this variable = 7.

7.7.11 Status_CalibrationVersion

The PEACE calibration is applied to produce data in scientific units within the IDFS VIDF files.
Each filename is constructed from the IDFS virtual name (which may be worked out from the `Mode_DataOrigin` variable and knowing which PEACE sensor is being used) followed by a string of numbers followed by the letters “V” or “V.v3”.
The string of numbers correspond to the *start* time from which that particular VIDF file is valid, in the form yyyyMMddhhmm where yyyy = year, ddd = day of year, hh = Hour of day, and mm = minutes. No two VIDFs may overlap a region of time, so this is a unique identifier when combined with the virtual name.

The first element is therefore this number string.
The second element, the source, is ground and =2
The third element is the version number of the VIDF (which may be a float rather than an integer). An exception is the MOMENTS product which is manufactured by the PI team, for which the archive date of the VIDF is given, as the VIDF version number is given elsewhere in the file).

For instance, a 3DR product for the HEEA sensor may have been combined with an IDFS VIDF file named DP3DRH20011821512V.v3 to produce the 3DR data in to units of PSD.

Status_CalibrationVersion[0] = 20011821512	(i.e. time string in VIDF filename 2001-07-01T15:12Z)
Status_CalibrationVersion[1] = 2	(i.e. ground source)
Status_CalibrationVersion[2] = 5	(i.e. VIDF version number)

Note here that the VIDF filename deals with time to the minute resolution only.

Be warned that while normally the CEF headers provide a useable SCALEMIN and SCALEMAX header information for each variable to be used for plotting purposes, the sheer difference in magnitude of numbers shown above means that it is not a useful guide for all three elements here.

7.7.12 Status_PEACErawData

The raw PEACE data is stored in the IDFS format as header and data files and are not given in scientific units. (The VIDFs are used to translate them later).

Each filename is constructed from the IDFS virtual name (which may be worked out from the `Mode_DataOrigin` variable and knowing which PEACE sensor is being used) followed by a string of numbers followed by the letter “H” or “D”. The header (H) and data (D) files work as a pair, so both are required, so each pair share the same filename with the exception of the last letter.
The string of numbers correspond to the *start* time from which that particular H and D file is valid, in the form yyyydddhhmm where yyyy = year, ddd = day of year, hh = Hour of day, and mm = minutes. No two H and D pairs may overlap a region of time with another pair, so this is a unique identifier when combined with the virtual name.

The first element is therefore this number string.
The second element, the source, is onboard the spacecraft and =1
The third element is the version number of the software used to ingest this raw spacecraft data in to IDFS format. An exception is the MOMENTS product which is manufactured by the PI team, for which the archive date of the file is given, to ensure traceability.

For instance, a 3DR product for the HEEA sensor may have used an IDFS Header/Data file pair named DP3DRH20011821512H and DP3DRH20011821512D.

Status_PEACErawData[0] = 20011821512	(i.e. time string in IDFS H/D filename 2001-07-01T15:12Z)

Status_PEACErawData[1] = 1 (i.e. onboard source, as it's encoded count data)
Status_PEACErawData[2] = 1 (i.e. Software version of ingestion code into IDFS)

Be warned that while normally the CEF headers provide a useable SCALEMIN and SCALEMAX header information for each variable to be used for plotting purposes, the sheer difference in magnitude of numbers shown above means that it is not a useful guide for all three elements here.

7.7.13 Status_PADSelectionQuality

The onboard pitch angle selection used to make PAD uses onboard IEL FGM data, which is less accurate than ground based FGM data (see 3.5.2.1). The software used to select the polar and azimuth data will fail in some known situations (e.g. field direction varies near azimuth 180 degrees). The PAD selection is also likely to be incorrect if the magnetic field is rapidly changing, as the data selection is based on FGM IEL data from previous spins.
The true pitch angle of the polar-azimuth combination which was selected onboard to represent 0/180 pitch angle is calculated using ground calibrated magnetic field data, in order to test how well the onboard selection worked.

Status_PADSelectionQuality	Definition
1	Pitch angle coverage is 0°-180° in both half-spins
2	Pitch angle coverage is 0°-180° in first half-spin only
3	Pitch angle coverage is 0°-180° in second half-spin only
4	Neither half spin had complete pitch angle coverage

7.7.14 Status_PitchAngleCoverage

This flag provides the user with information on the actual pitch angle coverage of each sensor, each half spin, in the PITCH_FULL product (derived from PAD). The flag may be useful in interpreting the PITCH_FULL data, or in pre-selecting data for statistical studies. The flag is produced by the same method as the Status_PADSelectionQuality flag.

Status_PitchAngleCoverage	Definition
1	pitch angle coverage is 0° to 180°
2	pitch angle coverage is 15° to 165°
3	pitch angle coverage is 30° to 150°
4	pitch angle coverage is 45° to 135°
5	pitch angle coverage is 60° to 120°
6	pitch angle coverage is 75° to 105°

7.7.15 Status_PenetratingRadiationRemoved

This flag will be renamed Status_PenetratingRadiation. It will be set when significant levels of background due to background radiation are thought to be present, which cause demonstrable errors in Moments data. Possible causes are Solar Energetic Particles and terrestrial radiation belt particles.

Unwanted signals are sometime seen in PEACE data which are due to penetrating radiation (ie. energetic particles able to pass through the material of the PEACE sensor heads and then to trigger a strong signal in the PEACE microchannel plate detector). Typically these can be recognised as a signal in each spin at the same level at all energies, in all look directions, superimposed on the signatures of the plasma electrons that PEACE is intended to measure.

The flag writing software is currently under development. In the present version, the flag is produced using data from the HEEA and LEEA sensors, and so is unavailable if one of the sensors is not turned on. The partial density from the two sensors in the HEEA/LEEA energy overlap region is compared. Provided that the inter-sensor calibration is accurate, the ratio of the LEEA and HEEA overlap region density should be close to 1. However, if the count rates are dominated by penetrating radiation, the ratio is expected to rise. This test is applied for times near perigee, defined using the JSOC catalogue "predicted scientific event" codes identifying crossings of the auroral oval. The test is also applied during SEP Intervals defined using a list available at the NOAA Space Weather Prediction Centre (http://www.swpc.noaa.gov/ftpdir/indices/SPE.txt), testing several days after the event onset.

The density data used is partial density data calculated onboard and with correction during ground processing for MCP gain variations. These data are not vulnerable to the problems discussed in Appendix C7, although very high fluxes may also lead to HEEA density underestimates if the limits of the HEEA micro-channel plates ability to respond strongly to all incident electrons are reached. Thus the test is not applied to magnetosheath or cusp intervals.

Consideration is being given to using RAPID IES fluxes as a supporting indicator, In particular for handling SEP events and cases where only one PEACE sensor is active.

Status_PenetratingRadiation	Definition
0	No background due to penetrating radiation
1	Caution: possible penetrating radiation counts
2	Warning: significant penetrating radiation counts

7.7.16 Status_SpacecraftPotential

The value is the spacecraft potential in eV used in the moments integration for the related spin record.

7.7.17 Status_CalculationMethod

The value is 0 to represent the standard method used at MSSL to integrate over the measured electron velocity distribution. If alternative methods are introduced in future work, it will be necessary to define other flag values, in which case the ICD will be updated.

7.7.18 Status_IntegrationLowerLimit

The value is the lowest energy in eV used in the moments integration for the related spin record.

7.7.19 Status_IntegrationUpperLimit

The value is the highest energy in eV used in the moments integration for the related spin record.

7.7.20 Status_WarningPartialCoverage

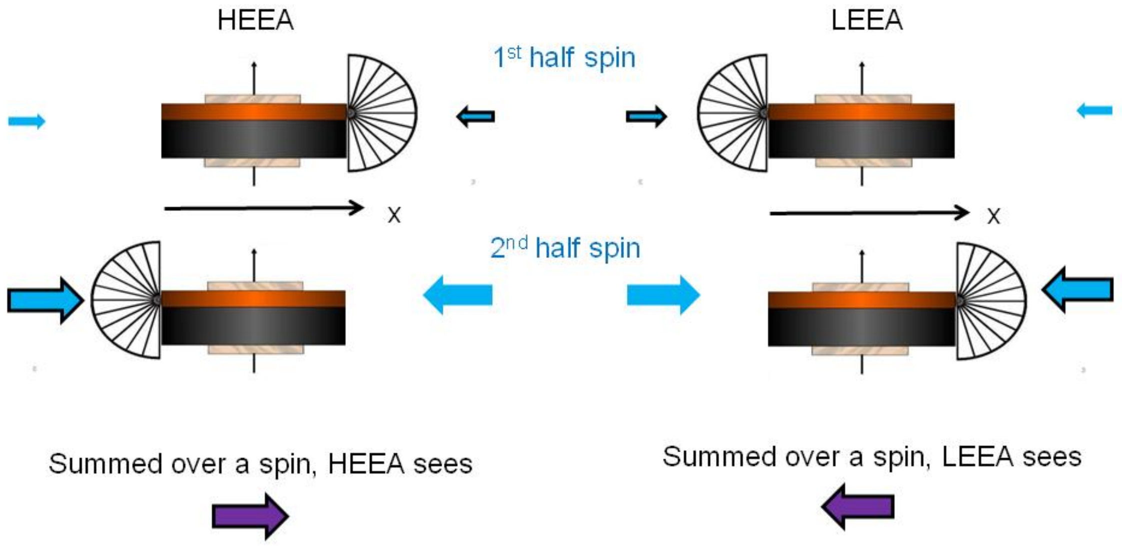
This flag identifies clear cut cases of partial coverage of the energy range occupied by the electron population, by the PEACE sensors, using the flag values given here.

Status_WarningPartialCoverage	Definition
0	Full coverage
1	Full coverage, Caution: Check low-energy population
2	Full coverage, Caution: Poorly resolved lobe population
3	Partial coverage at low energies
4	Partial coverage at high energies
5	Partial coverage at low and high energies
6	Caution: Very low counts – see also Status_CountStats

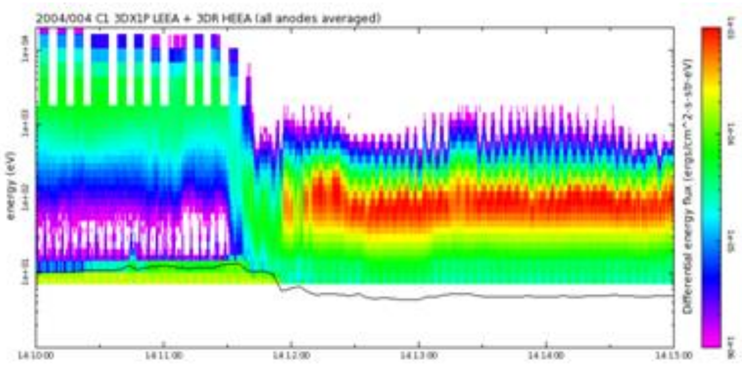
7.7.21 Status_WarningTimeAliasing

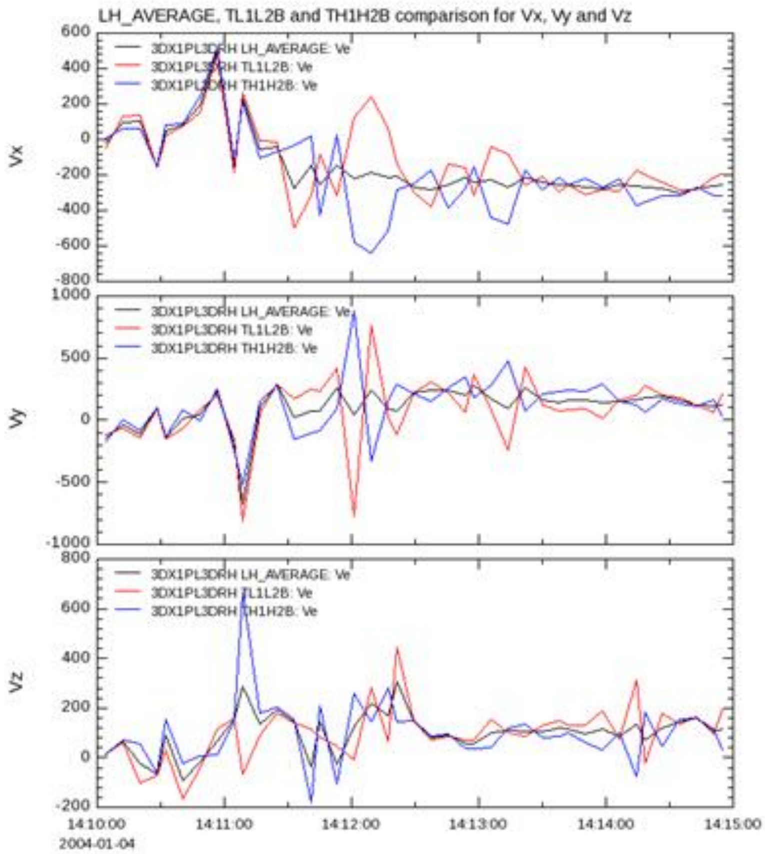
This status variable is still being worked on and the following represents our current plans.

In the simplest situation, the fluxes surrounding the spacecraft may be monotonically changing during the spin, in which case we can expect a characteristic signature in the PEACE data, provided both sensors are covering the relevant energy range. The figure below shows that we may expect that the spin plane components of the velocities calculated using HEEA data and LEEA data separately to show equal and opposite values, if the fluxes change systematically during a spin. The velocity magnitude will also be in error at such times.



The figure below demonstrates this using an example of PEACE data at a magnetopause crossing. The blue and red traces represent spin plane components of the velocity moments calculated from HEEA and LEEA respectively. The black traces show the result of averaging moments calculated during the first half spin and the second half spin, where the HEEA and LEEA data in the energy overlap region are combined to provide full 4π solid angle coverage In each half spin (as in the cartoon above).





This flag is currently under development, based on the identification of intervals with "mirror image" HEEA and LEEA spin plane velocity components in the energy overlap region as described above.

8 SUB RECORD TIMING:

[An fuller explanation including an example will be added to this appendix in a later release of this document.]

All angles are in degrees, and variables in bold are as those specified in section 5.2.6.7. Since this is concerned with sub-record timings of azimuths, each Azimuth will be referred to by index *i*. The symbol "…" means that the equation continues on the next line.

SpinDuration = **time_tags_DeltaLower** + **time_tags_DeltaUpper**

Centre of an Azimuth has a time tag of,
time_tags_Azimuth[*i*] = **time_tags** – (**Angle_SR2phi** – …
Sweep_Azimuth[*i*])*SpinDuration/360

More usefully, the start and end time of a particular azimuth within a record may be calculated as:

time_tags_Azimuth[*i*]_Start = **time_tags** – (**Angle_SR2phi** – …
{**Sweep_Azimuth**[*i*] – **Sweep_Azimuth_DeltaLower**[*i*]})*SpinDuration/360

time_tags_Azimuth[*i*]_End = **time_tags** – (**Angle_SR2phi** – …
{**Sweep_Azimuth**[*i*] + **Sweep_Azimuth_DeltaUpper**[*i*]})*SpinDuration/360

Once the time span of an azimuth is known it is possible to work out the time span of an individual energy (or fly-back) bin within that azimuth. For instance if there are 16 energy/fly-back bins then divide the time span of the azimuth in to 16 equal sections. The real number of energy/fly-back bins is given by the third element of the Mode_RealSize variable, note this is not the variable Data's Size parameter.

Due to rounding errors the results may not be exactly the same as the IDFS azimuth times – but they should be good to within a few milliseconds.

Example

Consider the following LER record from Cluster 1 LEEA in units of counts, where we wish to work out the time of the second azimuth – highlighted in blue. Other values used are shown in bold.

```
2001-07-01T00:00:08.735Z, 2.01, 2.01,  308.567,

3,  79, 76, 16,  51.814, 8.716,  17,   5,
8, 3, 8,  8,

46.727, 38.015, 29.885, 23.879, 19.632, 16.009, 12.439,  9.612,-1,-1,-1,-1,-1,-1,-1,-1,
 4.515,  4.025,  3.292,  2.229,  1.758,  1.305,  2.136,  0.896,-1,-1,-1,-1,-1,-1,-1,-1,
 5.087,  4.197,  4.105,  2.714,  2.018,  1.865,  2.265,  0.691,-1,-1,-1,-1,-1,-1,-1,-1,

154.26, 199.22, 244.22, 289.22, 334.22,  19.22,  64.22, 109.22,
   1.4,   1.44,   1.44,   1.44,   1.44,   1.44,   1.44,   1.44,
  1.39,   1.44,   1.44,   1.44,   1.44,   1.44,   1.44,   1.44,

    48,     42,     42,     38,     30,     22,    256,    416,-1,-1,-1,-1,-1,-1,-1,-1,
    92,     80,     48,     52,     22,     36,    336,    384,-1,-1,-1,-1,-1,-1,-1,-1,
    60,     60,     48,     38,     28,     32,    304,    400,-1,-1,-1,-1,-1,-1,-1,-1,

    48,     42,     44,     38,     28,     34,    304,    400,-1,-1,-1,-1,-1,-1,-1,-1,
    48,     48,     42,     38,     30,     52,    320,    336,-1,-1,-1,-1,-1,-1,-1,-1,
    64,     52,     36,     34,     30,     38,    336,    432,-1,-1,-1,-1,-1,-1,-1,-1,
```

```
    80,     56,     60,     40,     36,     56,    320,    416,-1,-1,-1,-1,-1,-1,-1,-1,
    68,     60,     44,     32,     40,     72,    352,    336,-1,-1,-1,-1,-1,-1,-1,-1,
    48,     52,     32,     32,     32,     64,    352,    464,-1,-1,-1,-1,-1,-1,-1,-1,

    76,     72,     60,     38,     28,     46,    288,    352,-1,-1,-1,-1,-1,-1,-1,-1,
    72,     92,     60,     46,     24,     64,    384,    416,-1,-1,-1,-1,-1,-1,-1,-1,
    42,     48,     44,     42,     24,     48,    320,    448,-1,-1,-1,-1,-1,-1,-1,-1,

    84,     68,     34,     40,     22,     38,    272,    368,-1,-1,-1,-1,-1,-1,-1,-1,
    68,     76,     68,     40,     40,     60,    384,    464,-1,-1,-1,-1,-1,-1,-1,-1,
    40,     38,     36,     32,     36,     36,    304,    384,-1,-1,-1,-1,-1,-1,-1,-1,

    52,     64,     42,     26,     22,     48,    288,    368,-1,-1,-1,-1,-1,-1,-1,-1,
    40,     44,     56,     34,     28,     48,    416,    496,-1,-1,-1,-1,-1,-1,-1,-1,
    56,     52,     32,     46,     32,     42,    320,    448,-1,-1,-1,-1,-1,-1,-1,-1,

    48,     48,     44,     38,     28,     44,    288,    368,-1,-1,-1,-1,-1,-1,-1,-1,
    88,     60,     52,     40,     26,     68,    336,    432,-1,-1,-1,-1,-1,-1,-1,-1,
    68,     64,     60,     36,     28,     36,    320,    448,-1,-1,-1,-1,-1,-1,-1,-1,

    52,     36,     40,     44,     24,     46,    240,    400,-1,-1,-1,-1,-1,-1,-1,-1,
    96,    100,     80,     44,     28,     48,    320,    384,-1,-1,-1,-1,-1,-1,-1,-1,
    96,     68,     48,     60,     40,     38,    256,    384,-1,-1,-1,-1,-1,-1,-1,-1,


 90.27,  90.31,  90.38,  90.45,  90.52,  90.59,  90.63,   90.7,-1,-1,-1,-1,-1,-1,-1,-1,
 37.25,  37.38,  37.64,  37.88,  38.14,  38.41,  38.55,   38.8,-1,-1,-1,-1,-1,-1,-1,-1,
  36.8,  36.87,  37.01,  37.15,  37.29,  37.45,  37.53,  37.67,-1,-1,-1,-1,-1,-1,-1,-1,

105.95, 106.13, 106.32, 106.52, 106.73, 106.83, 107.04, 107.23,-1,-1,-1,-1,-1,-1,-1,-1,
 74.78,  75.15,  75.48,  75.84,  76.21,   76.4,  76.78,  77.11,-1,-1,-1,-1,-1,-1,-1,-1,
  57.5,  57.72,  57.88,  58.06,  58.25,  58.35,  58.55,  58.72,-1,-1,-1,-1,-1,-1,-1,-1,

126.82, 127.04, 127.27, 127.51, 127.64, 127.82, 128.01, 128.21,-1,-1,-1,-1,-1,-1,-1,-1,
111.92, 112.31, 112.74, 113.17, 113.41,  113.7, 114.02, 114.35,-1,-1,-1,-1,-1,-1,-1,-1,
 76.94,  77.13,  77.35,  77.56,  77.68,  77.81,  77.95,   78.1,-1,-1,-1,-1,-1,-1,-1,-1,

145.51, 145.59, 145.67, 145.71, 145.79, 145.86, 145.93, 146.01,-1,-1,-1,-1,-1,-1,-1,-1,
146.63, 146.85, 147.08,  147.2, 147.42, 147.62, 147.84, 148.04,-1,-1,-1,-1,-1,-1,-1,-1,
 90.63,   90.7,  90.78,  90.82,   90.9,  90.97,  91.04,   91.1,-1,-1,-1,-1,-1,-1,-1,-1,

143.71, 143.59, 143.46, 143.39, 143.25, 143.13, 142.99, 142.85,-1,-1,-1,-1,-1,-1,-1,-1,
145.02, 144.81, 144.59, 144.48, 144.25, 144.05, 143.83,  143.6,-1,-1,-1,-1,-1,-1,-1,-1,
 90.76,  90.71,  90.66,  90.64,  90.59,  90.55,   90.5,  90.45,-1,-1,-1,-1,-1,-1,-1,-1,

123.04, 122.82, 122.59, 122.47, 122.25, 122.02, 121.77, 121.65,-1,-1,-1,-1,-1,-1,-1,-1,
110.64, 110.27, 109.89, 109.69, 109.33, 108.94, 108.54, 108.34,-1,-1,-1,-1,-1,-1,-1,-1,
 78.88,  78.72,  78.56,  78.47,  78.31,  78.14,  77.96,  77.87,-1,-1,-1,-1,-1,-1,-1,-1,

102.03, 101.85, 101.66, 101.56, 101.39, 101.21, 101.03, 100.84,-1,-1,-1,-1,-1,-1,-1,-1,
 72.04,  71.69,  71.33,  71.14,   70.8,  70.46,  70.11,  69.73,-1,-1,-1,-1,-1,-1,-1,-1,
 58.88,   58.7,  58.51,  58.41,  58.24,  58.07,  57.89,  57.69,-1,-1,-1,-1,-1,-1,-1,-1,

 87.46,  87.39,  87.36,  87.29,  87.24,  87.17,  87.11,  87.08,-1,-1,-1,-1,-1,-1,-1,-1,
 33.34,  33.06,  32.93,  32.64,   32.4,  32.14,  31.87,  31.73,-1,-1,-1,-1,-1,-1,-1,-1,
 37.72,  37.57,   37.5,  37.36,  37.24,  37.11,  36.98,  36.92,-1,-1,-1,-1,-1,-1,-1,-1,


1,-1,-1, -1,-1,-1, 0,-1,-1, 1,-1,-1, -1,-1,-1, -1,-1,-1, -1,-1,-1, -1,2,1.7, -1,-1,-1
$
```

The calculations are then:

```
SpinDuration = time_tags_DeltaLower + time_tags_DeltaUpper
             = 2.01                 +  2.01
             = 4.02 seconds

time_tags_Azimuth[2]_Start    = time_tags - (Angle_SR2phi - …
          {Sweep_Azimuth[2] - Sweep_Azimuth_DeltaLower[2]})*SpinDuration/360
      = 2001-07-01T00:00:08.735Z - (308.567 - {199.22 - 1.44})*4.02/360
      = 2001-07-01T00:00:08.735Z - (          110.787       )*4.02/360
      = 2001-07-01T00:00:08.735Z - 1.237 seconds
      = 2001-07-01T00:00:07.498Z

time_tags_Azimuth[2]_End      = time_tags - (Angle_SR2phi - …
          {Sweep_Azimuth[2] + Sweep_Azimuth_DeltaUpper[2]})*SpinDuration/360
      = 2001-07-01T00:00:08.735Z - (308.567 - {199.22 + 1.44})*4.02/360
      = 2001-07-01T00:00:08.735Z - (          107.907       )*4.02/360
      = 2001-07-01T00:00:08.735Z - 1.205 seconds
      = 2001-07-01T00:00:07.530Z
```

Therefore the 2nd azimuth is from time `2001-07-01T00:00:07.498Z` to `2001-07-01T00:00:07.530Z`, duration of 0.032 seconds.

For comparison, the IDFS time stamp for that azimuth was a start time of 2001-07-01 00:00:07.504 with a duration of 31.248 ms. While not exact due to rounding errors – this is still very good to within a few milliseconds and a cast improvement on spin resolution times at ~4 second intervals.

From the record it is clear there are 8 energies per azimuth (from the 3rd element of variable Mode_RealSize), such that each energy bin lasts (0.032/8 s =) 4ms. From here it is simple to work out the time of each bin:

[Note that the LER Data's Size parameter is 16, not 8, but that the extra 8 is made up of fill values and may therefore be discarded.]

```
Energy bin 1: 2001-07-01T00:00:07.498Z to 2001-07-01T00:00:07.502Z
Energy bin 2: 2001-07-01T00:00:07.502Z to 2001-07-01T00:00:07.506Z
Energy bin 3: 2001-07-01T00:00:07.506Z to 2001-07-01T00:00:07.510Z
Energy bin 4: 2001-07-01T00:00:07.510Z to 2001-07-01T00:00:07.514Z
Energy bin 5: 2001-07-01T00:00:07.514Z to 2001-07-01T00:00:07.518Z
Energy bin 6: 2001-07-01T00:00:07.518Z to 2001-07-01T00:00:07.522Z
Energy bin 7: 2001-07-01T00:00:07.522Z to 2001-07-01T00:00:07.526Z
Energy bin 8: 2001-07-01T00:00:07.526Z to 2001-07-01T00:00:07.530Z
```

So to find the time of the third energy bin (shown in bold blue in the record) is:
`2001-07-01T00:00:07.506Z to 2001-07-01T00:00:07.510Z`