ANNEX 3

SPI SCIENCE DATA FORMAT SPECIFICATION

Ref. : DSO/ED/DI/SI-138

INTERNATIONAL GAMMA RAY ASTROPHYSICS LABORATORY

SPI SCIENCE DATA FORMAT SPECIFICATION

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DOCUMENTATION CHANGE RECORD

Issue	Revision	Date	Modified Pages	Observations
1	0	02/03/99	All	First Issue
2	0	04/02/99		DM 320, DM 312, DM 261,DM 336, DM 337
2	1	07/04/00		New chapter for post-processing algorithm of PSD science data, plotting PSD curves data: DM 358 Precision about parity flag when Word Count equals 0: DM 362 ME: pure PSD + PSD event in ME; no PE in cal mode: DM 359

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2	2	12/07/00		The curve transmission rates are the same for calibration and diagnostic mode; more information about setting of parity flag and data flow according to modes: DM 366 Word of science data equals 0 when there is a correlation failure; precision about format of PSD curves sub-block when correlation is enabled or not with changes concerning the order of words energy and time: DM 367 Format of PE and ME when parameter RouteMode of DFEE is set to RouteACtoPSD: DM 369 Energy bit range for events data from AFEE: DM 372 Spectre implementation: DM 378 PSD data organization on HSL is the same for CAL, OPER and DIAG modes: DM 382
2	3	26/06/01		SPI DPE Redundant/Nominal APID: DM 422 Clarification of Post-processing algorithm of PSD science data (error code) TBC "APID for spectra packet" raised. TBC HSL length raised Implementation of AFEE manual mode: DM 344
2	4	25/02/03	See vertical lines	Some clarification about bit R and spectra DM 561: clarification about compression (applicable since IASW version 4.1.0)
2	5	15/09/03		SPI-DM-0-576-CNES Pages III, 5

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1. INTRODUCTION

This note describes the flow and structure of the scientific data delivered by the Spectrometer on INTEGRAL. The SPI camera (Detector chains, AFEE) digitizes the photon events and sends the event energy to the DFEE while PSD sends event shape characteristics to DPE and an identifier of event to DFEE. This equipment sorts the events (single, multiple or PSD processed events) and sends this data to the DPE. The IASW runs in the DPE and calculates accumulated spectra according to the energy of the events. It makes also an operation called "correlation" that consists to associate, by the way of identifier label, shape characteristic provided on PSD HSL link and energy provided on DFEE HSL link in order to construct PSD events and PSD curves. Then all these data are encapsulated in Telemetry Packets that are downlinked to ground at a rate corresponding to the SPI allocation of TM.

This note gives all useful information to build ground algorithms for scientific data decoding.

2. REFERENCE DOCUMENTS

RD1: SPECTROMETER USER MANUAL Ref.: SPI-0-1062-CNES

RD2: SPI INTERFACE SPECIFICATION Ref.: SPI-0-1324-CNES

RD3: INTEGRAL PACKET STRUCTURE DEFINITION Ref.: SPI-CR-0/SAT-1549-AL

3. DATA TYPE DESCRIPTION

The events are processed by the SPI IASW and result in different types of data which are identified by both the on board channel of transmission (Low Speed Link or High Speed Link) and by the physical classification of the event. The SPI permits to select by configuration some types of data depending on environmental bursts, solar activity, it also optimizes in real time the downlinked data according to the actual TM rate and the scientific priorities.

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3.1. TYPES OF DATA

The DFEE, being the core of the SPI, sorts the data associated to the events into the 4 different physical types of events: SE for single events, ME for multidetector events, PE for events processed by PSD, SP for spectra events. The incoming events when detected by the Anti-Coincidence System are called vetoed events, and the DFEE can be programmed to discard the vetoed events or to keep them for SP. These 4 types of data are transmitted to DPE through the HSL, thus making that HSL transfers only scientific data.

The DFEE keeps counting the number of events detected either by the PSD, by the ACS or by each detector chain sorting the latter in saturated or non-saturated events. All these counters are transmitted through the LSL and are called in RDs Housekeeping Scientific Data.

The Anti-Coincidence System counts continuously the number of detected events in so called Overall Counters as well as it cycles counting round the 92 FEEs for monitoring purposes. All these counters are transmitted through the LSL link and belong to the Housekeeping data type. (refer to RD 1)

3.2. DATA FLOW ACCORDING TO MODES

The scientific data is generated by SPI only during the scientific modes: OPERATIONAL, CALIBRATION, DIAGNOSTIC, EMERGENCY. (refer to RD1)

Type of Data\SPI mode	OPERATIONAL	CALIBRATION	EMERGENCY	DIAGNOSTIC
SE	Yes	No	No	Yes
ME	Yes	No	Yes	Yes
PE	Yes	No	No	Yes
PC (PSD curves)	Yes	Yes	No	Yes
Spectra	Yes*	No	Yes**	Yes*

Yes*: the events included in the spectra are the events contained in DFEE SP sub-block (which depends on a configuration parameter of DFEE (vetoed events or SE Non-vetoed or all events, or nothing))

Yes**:the events included in the spectra are the events contained in DFEE SP sub-block (which depends on a configuration parameter of DFEE (vetoed events or SE Non-vetoed or all events, or nothing)) and the events added by IASW depending on a configuration parameter of IASW (all PSD with passed correlation or Multiple PSD with passed correlation)

4. DATA STRUCTURE DEFINITION

The SPI IASW builds separately the packets of the Scientific Housekeeping data, the spectra and the photon characterisation. All these packets are identified by different APIDs (refer to Vol 4 of RD1). The equivalent

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APID of the SPI redundant part is obtained by adding 128 to the APID of the SPI nominal part (refer to Vol 1 of RD1).

4.1. SCIENTIFIC HOUSEKEEPING DATA

This data is contained in 5 different TM packets with APIDs 1120-1124 (1248-1252 for redundant DPE); these packets are cyclic and downloaded each 8 Sec (refer to Vol 4 of RD1). The elementary counters contained in these packets are accumulating some type of events during 1 Sec; so each 8 Sec, 8 different values of each counter will be downloaded for each second accumulation. The packets of APID 1120-1123 (1248-1251 R) contain the counters values for 2 Sec each: e.g. APID 1120 (1248 R) contains counters values for the 1st and the 2nd Second of the 8 Sec time frame, and so on. The packet APID 1124 (1252 R) contains some counters and the time frame clock monitor for each Second of the 8 Sec time frame. This packet contains 8 times the elementary block Id 0B Hex (one per second), the block itself contains the 8 values of 8 Hz clock monitor for one Second.

The counters for the 2 first seconds after the mode change to any scientific mode as well as the counters for the last second before exiting any scientific mode can be corrupted.

Refer to RD1 for description of the counters.

4.2. PHOTON CARACTERISATION PACKETS

The photon data is generated on a 125mSec basis and repetitive structure. This data is referred to as 125mSec_pattern. Of course the size of this 125mSec_pattern is variable depending on the number of events. To optimize the efficiency of telemetry flow, the 125mSec_patterns are concatenated to use all the available size of the TM packets. These packets have different APIDs according to the current mode of SPI:

Nominal APID	SPI mode	Redundant APID
1088	OPERATIONAL	1216
1089	EMERGENCY	1217
1090	CALIBRATION	1218
1091	DIAGNOSTIC	1219

The structure of the packets is the same for all these APIDs

4.2.1. Packet structure description

According to incoming events, the size of one 125mSec_pattern can be either less or greater than the size of one TM packet (428 bytes). The photon data must be considered as a continuous flow of the following elementary sequence:

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[Synchronisation pattern, (OBT of current 8Hz cycle, 125mSec_pattern)*64],
[Synchronisation pattern, (OBT of current 8Hz cycle, 125mSec_pattern)*64],
[Synchronisation pattern, etc...]

Refer to Figure 4.2.4-1 and Figure 4.2.4-2

In this two figures, Packet Header (48 bits), Data Field Header (32 bits) and CRC Field (16 bits) are represented (see RD3 for further description)

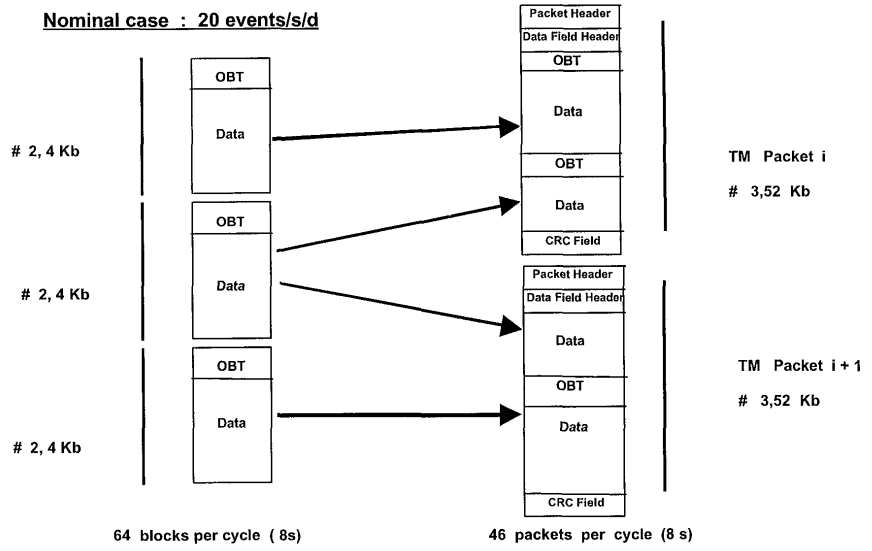

FIGURE 4.2.1-1

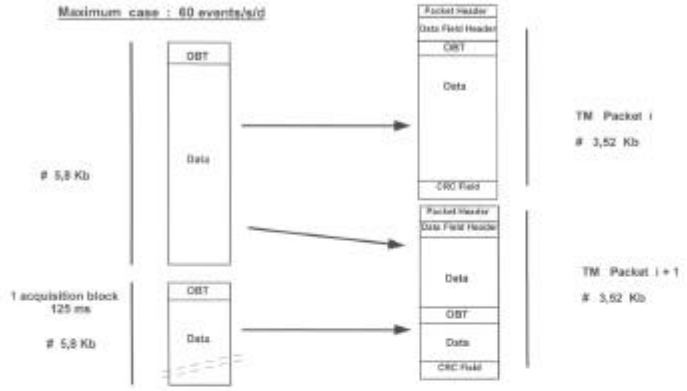

FIGURE 4.2.1-2

Splitting this continuous flow in 428 bytes TM packets can make the packet edge lie on any byte of the elementary sequence.

The Synchronisation pattern is made of 4 words of 16bits inserted each 64 125mSec acquisition block effectively downloaded.

This synchronisation pattern value is defined as falkows :

.When the ME block are processed by the ME reduction algorithm, the synchronisation pattern is : 7670 D48C 7670 D48C (new format, new synchro)

. when the Me block are not processed by the ME reduction algorithm, the synchronisation pattern is : 7670 D48B 7670 D48B (old format, old synchro)

It is to be noted that when a 125mSec acquisition block is not downloaded due to buffer overflow on-board, it should not be taken into account for the word synchronisation interval. In this case the time interval between two synchronisation words is > 8Sec

The OBT of the current 8 Hz cycle is the value of the datation of the beginning of the cycle; the OBT is coded on 43 bits; the five least significant bits of the 3 words are meaningless; the least useful bit weight is 2**-19 Sec = 1.907µSec.

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4.2.2. 125mSec_pattern structure description

Remark: In this paragraph, all the time related data resolution is based on a 50 nSec clock.

The 125mSec_pattern has the structure described in the following table:

Number of words in the 125mSec_pattern excluding itself (size 1 word)
Single events SE (size variable) Word Count for SE
Multiple events ME (size variable) Word Count for ME
PSD events PE (size variable) Word Count for PE
PSD curves (size variable) Word Count for curves

It always contains 5 sub-blocks:

- the number of words contained in the 125mSec_pattern
- the single events sub-block
- the multiple events sub-block
- the PSD events sub-block
- the PSD curves sub-block

When a sub block does not contain any data, its WC (word count) is set to 0.

4.2.2.1. THE NUMBER OF WORDS CONTAINED IN THE 125MSEC_PATTERN

On one word, this field gives the length in 16bits words of the 125mSec_pattern, excluding itself.

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4.2.2.2. THE SINGLE EVENTS SUB-BLOCK

This sub-block has the following structure

Word N°1	**Single Events data**
Word N°2	
Word N°i	
Word N°i+1	**Single Event trailer**

4.2.2.2.1. SINGLE EVENT TRAILER

The Single Event trailer has the following format:

Partial flag	Parity flag	Word Count
15	14	13 ... 0

4.2.2.2.1.1. Word Count

Gives the number of words of 16bits in the sub-block, excluding itself. Valid range is [0..8192] inclusive. A value of 8192 indicates that the DFEE had to discard SE events during the corresponding 125 ms interval, due to internal storage limitations; in that case, the sub-block contains the first 4096 SE events detected in this interval (the following structure of SE data is guaranteed). Word Count values higher than 8192 are invalid.

4.2.2.2.1.2. Parity flag

Equals "1" when a parity error was detected in the ASIC. This status bit indicates that at least one of the SE events was altered during temporary storage in the DFEE.

4.2.2.2.1.3. Partial flag

Equals "1" when the DFEE could not send all the SE data within the current 125 mSec cycle, due to lack of space in the HSL packet. In that case, the corresponding ME and PE sub-blocks are empty. In the foreseen flight configuration, the partial flag will not be set on the SE sub-block because the chosen HSL packet length (HslXferLength, E7783 = 3072) is large enough to contain even the largest SE sub-block.

Remark: When there is a problem in IASW during analysis of HSL data, the SE sub-block downloaded in TM is made empty by the IASW: the last word is set to 4000 Hex (parity flag set to 1 and word count set to 0). In calibration and emergency modes, the last word is also set to 4000 Hex by the IASW because the SE sub-block is not downloaded in these modes.

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4.2.2.2.2. SINGLE EVENTS DATA

The single event data gives the list of SE events encountered during the current 125 ms interval, ordered in increasing time of occurrence. Each following SE event occupies a fixed space (2 words). The SE event data comes in the following format:

	MSB			LSB
	15	14	13	0
Single Event N° 1	R	S	Energy	
	Time			Detector number
Single Event N° 2	R	S	Energy	
	Time			Detector number
Single Event N° i	R	S	Energy	
	Time			Detector number
	15		5	4 0

R: indicates the energy range where "0"=[0KeV..2MeV] and "1"=[2MeV..8MeV];

S: spare bit equals "1";

Energy: 14 bits for energy conversion value, as it was received from the AFEE;

Detector number: identifies the detector chain, ranging from 0 to 12 Hex;

Time: Time of occurrence of event (AFEE TT), counted from beginning of 8Hz cycle (0 to 2047, unit = 102.4µSec.

When the DFEE does not receive any energy value for a detected event before the delay defines by DFEE time out parameter TimeOutValMissNrj=E7776 (abnormal condition), then the value of the energy range bit, of the spare bit, and of the energy will be "0".

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4.2.2.3. THE MULTIPLE EVENTS SUB-BLOCK

This sub-block has the following structure

Word N°1	**Multiple Events data**
Word N°2	
Word N°i	
Word N°i+1	**Multiple Events trailer**

4.2.2.3.1. MULTIPLE EVENTS TRAILER

The Multiple events trailer has the following format:

Partial flag	Parity flag	Word Count
15	14	13 0

4.2.2.3.1.1. Word Count

Gives the number of words of 16bits in the sub-block, excluding itself. Valid range is [0..8192] inclusive. A value of 8192 indicates that the DFEE had to discard ME events during the corresponding 125 ms interval, due to internal storage limitations; in that case, the sub-block contains the first ME events detected in this interval, and the last ME event is generally truncated. Word Count values higher than 8192 are invalid.

4.2.2.3.1.2. Parity flag

Equals "1" when a parity error was detected in the ASIC. This status bit indicates that at least one of the ME events was altered during temporary storage in the DFEE.

4.2.2.3.1.3. Partial flag

Equals "1" when the DFEE could not send all the ME data within the current 125 mSec cycle, due to lack of space in the HSL packet. In that case, the corresponding PE sub-blocks is empty. In the foreseen flight configuration, the partial flag will not be set on the ME sub-block because the chosen HSL packet length (HslXferLength, E7783 = 3072) is large enough to contain both the largest SE and ME sub-blocks.

Remark: When there is a problem in IASW during analysis of HSL data, the ME sub-block downloaded in TM is made empty by the IASW: the last word is set to 4000 Hex (parity flag set to 1 and word count set to 0). In calibration mode, the last word is also set to 4000 Hex by the IASW because the ME sub-block is not downloaded in this mode.

4.2.2.3.2. MULTIPLE EVENTS DATA

The Multiple Events data gives the list of Multiple Events encountered during the current 125 ms interval, ordered in increasing time of occurrence. Each following Multiple Events occupies a variable space (from 3 to 63 words), depending on the number of elements it contains, and ends up with a label which gives its size. The Multiple Events data must be analysed by backwards chaining in the reverse direction, starting at the end of the list and hopping from a Multiple Events to the previous one until the first one has been reached.

4.2.2.3.2.1. Multiple Events structure

A Multiple Events gathers the activity of several detectors, for which the corresponding Time Tag sequence formed a cascade. The time distance between any two following elements of the cascade is smaller or equal to the DFEE AssoMultWinSize parameter (E7753). PSD Time Tags may be part of the cascade, at any position, and may create links between AFEE Time Tags, which would not be assembled otherwise. Cascades formed with PSD only information (Pure Psd) may be included in the ME sub-block if the DFEE EvtKeepPP parameter (E7780) is set.

4.2.2.3.2.2. Multiple Events format

A Multiple Events first gives the list of its elements, ordered in increasing time of occurrence, and ends up with a 1-word label which gives the number of elements and the time of occurrence of the first element.

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4.2.2.3.2.2.1. Multiple Events element

Each element of a Multiple Events occupies 2 words, and can be either of the AFEE or PSD type. The type is defined by the detector number field value in the second word.

AFEE element, 1st word

The first word of an AFEE element gives the Energy word as it was received from the AFEE. It is replaced by 0000hex if the AFEE did not produce the energy before the delay defined by DFEE time out parameter TimeOutValMissNrj E7776 (abnormal condition).

PSD element, 1st word

The 1st word of a PSD element shows two variants :

Variant 1 : Normal mode

In the normal mode of operation, the first word of a PSD element gives the PSD Id value, unmodified from what the PSD transmitted to the DFEE after its Time Tag. It is replaced by 0000hex if the PSD did not produce the Id before the DFEE time out, controlled by DFEE parameter TimeOutValMissNrj (E7776). The normal behaviour applies when the DFEE RouteMode parameter is set to its normal value NoRouting (E7846 = 0).

Variant 2 : Timing mode

In special modes devoted to AC gate timing, the PSD elements actually reflect the AC gate timing edges. Time out is not possible, and the PSD Id is forced to value 1D13hex. This value was chosen to avoid confusion with a normal Psd Id value. The timing behaviour applies when the DFEE RouteMode parameter is set to either RouteAcLeft (E7846 = 2) or RouteAcBoth (E7846 = 3).

AFEE or PSD element, 2d word

The second word of an element gives the detector number (00hex to 12hex for AFEE, 13hex for PSD) and the fine time interval from the previous element (right-justified ΔT field). When the element is the first element of the Multiple Event, the ΔT value (0,1 or 3) uses a special code that helps resolve timing ambiguities that may arise on the first two elements when they occur at one clock of each other.

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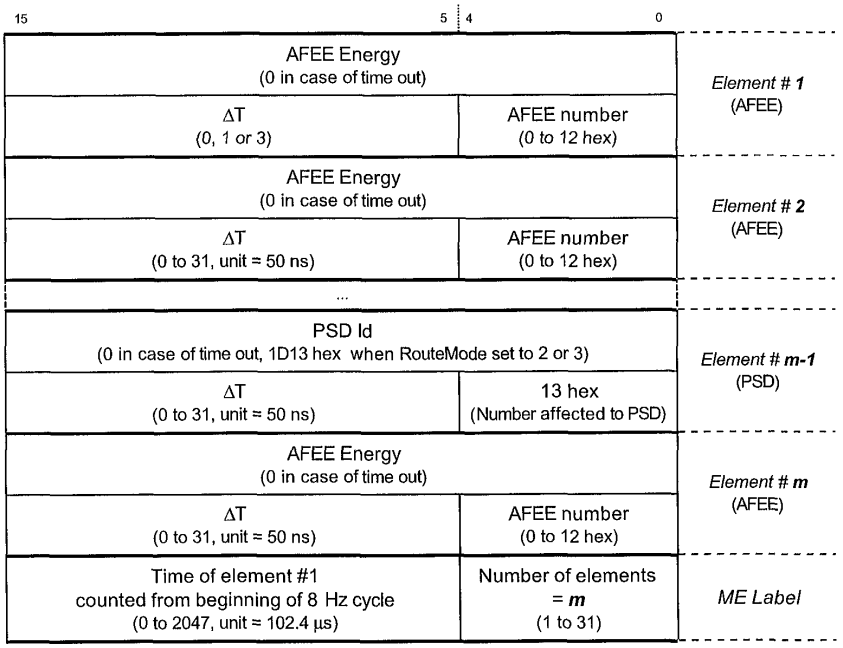
4.2.2.3.2.2.2. Generic ME format

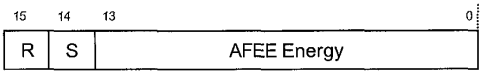
The generic format of a Multiple Events is detailed in the following diagram, which shows a m-element ME where both types of elements (AFEE and PSD) are illustrated.



Generic format of a m-element Multiple Event

AFEE Energy format

When not replaced by 0000hex due to time out, the AFEE Energy word shows the usual format :



R : indicates the energy range where "0" = [0KeV .. 2MeV] and "1" = [2MeV .. 8MeV] ;

S : spare bit equals "1" ;

Energy : 14 bits for energy conversion value.

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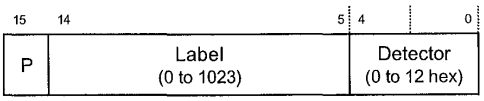
PSD Id format

When not replaced by 0000hex due to time out or forced to 1D13hex under special timing modes, the PSD Id word shows the following format :



P : Processing flag. Set to "1" when the PSD processed this particular Time Tag, "0" otherwise.

Label : An increasing, modulo-1024 number transmitted by the PSD to the DFEE in the identifier word after each Time Tag.

Detector : The number (00hex to 12hex) of the unique detector which triggered the PSD.

Remark : The 1D13hex value provided during timing modes cannot be confused with a normal PSD Id because it sets the detector field to the normally unaffected value 13hex.

4.2.2.3.2.2.3. DeltaT encoding

The ΔT field is encoded in a special way that helps analysing the mutual timing between any 2 AFEEs down to the 50 ns unit accuracy.

DeltaT from the second to the last element

The ΔT field gives the time elapsed from the previous element in the Multiple Event, expressed in 50 ns units, in the range [0..31].

DeltaT of the first element

A special value is used for the first element, to improve the timing resolution when the two first elements were detected at exactly one clock of each other.

ΔT first = 0 : The 2^d element is either simultaneous (and will then have itself ΔT = 0), or further away at a distance $n \geq 2$ (and will then have ΔT = n), or absent ;

ΔT first = 1 : The 2^d element is at a distance of exactly 1 unit, and the detector with the highest number was observed first ;

ΔT first = 3 : The 2^d element is at a distance of exactly 1 unit, and the detector with the lowest number was observed first.

When codes 1 or 3 are used, the order inside the ME does not necessarily reflect the initial order in time for the first 2 elements. However, the actual order in time may be recovered by analysing the numbers of the involved detectors.

4.2.2.3.2.2.4. **Special cases**

ME with PSD element(s)

ME events with one PSD element will occur in the flight configuration. A typical case is a 2-AFEE multiple, when the energy of one of the involved AFEEs is below the energy range of the PSD.

Analysis of the timing characteristics of both the AFEE and PSD electronics has shown that in the normal SPI configuration, ME events with more than one PSD element cannot be produced, whatever the DFEE configuration of AssoMultWinSize (E7753) may be. However, ME events with more than one PSD element will be produced by the DFEE when configured for timing.

Pure PSD ME

Pure PSD Multiple Events only contain PSD elements, and are maintained in the ME sub-block when DFEE parameter EvtKeepPP (E7780) is set. For PP events, the degenerated case of a Multiple Event with one single element is possible.

PP ME events with one single PSD element will occur in the flight configuration. A typical scenario is when the PSD triggers on a detector for which the AFEE is in dead time due to previous activity.

Again, analysis of the timing characteristics of both the AFEE and PSD electronics has shown that in the normal SPI configuration, PP ME events with more than one element cannot be produced, whatever the DFEE configuration of AssoMultWinSize(E7753) may be. However, PP ME events with more than one element will be produced by the DFEE when configured for timing.

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4.2.2.4. THE PSD EVENTS SUB-BLOCK

This sub-block has the following structure

Word N°1	PSD event data
Word N°2	
Word N°n	
Word N°n+1	PSD Event trailer

4.2.2.4.1. PSD EVENT TRAILER

The PSD Event trailer has the following format:

Partial flag	Parity flag	Word Count=n
15	14	13 ... 0

4.2.2.4.1.1. Word Count

Gives the number of words in the sub-block, excluding itself. Valid range is [0 .. 8192] inclusive. A value of 8192 indicates that the DFEE had to discard PE events during the corresponding 125 ms interval, due to internal storage limitations; in that case, the sub-block contains the first 2731 PE events detected in this interval, and the last PE event is truncated. Word Count values higher than 8192 are invalid.

4.2.2.4.1.2. Parity flag

Equals "1" when a parity error was detected in the ASIC. This status bit indicates that at least one of the PE events was altered during temporary storage in the DFEE.

4.2.2.4.1.3. Partial flag

Equals "1" when the DFEE could not send all the PE data within the current 125 ms cycle, due to lack of space in the HSL packet. In that case, only the first PE events detected in this interval are given, to the extend of the available space. Due to the 3-word span of PE events, the last PE event is generally truncated when Partial is set. In the foreseen flight configuration, the partial flag may be set on the PE sub-block because the chosen HSL packet length (HslXferLength, E7783 = 3072) is not large enough to contain the sum of the largest SE, ME and PE sub-blocks.

Remark: When there is a problem in IASW during analysis of HSL data, the PE sub-block downloaded in TM is made empty by the IASW: the last word is set to 4000 Hex (parity flag set to 1 and word count set to 0). In calibration and emergency modes, the last word is also set to 4000 Hex by the IASW because the PE sub-block is not downloaded in these modes.

Ref. : DSO/ED/DI/SI-138

4.2.2.4.2. PSD EVENTS DATA

The PSD Events data gives the list of PE events encountered during the current 125 ms interval, ordered in increasing time of occurrence. Each following PE event occupies a fixed space (3 words).

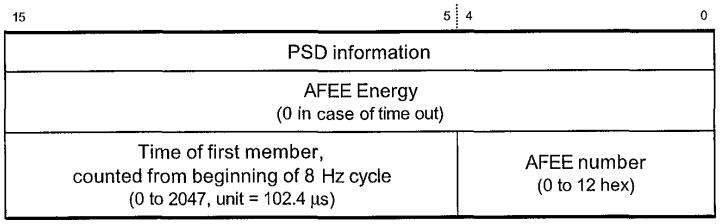
4.2.2.4.2.1. Psd Event formation

A PSD Event assembles the information coming from exactly one AFEE channel and from the PSD, when their respective Time Tags lie within a time distance which is smaller or equal to the DFEE AssoMultWinSize parameter (E7753). In the normal mode of operation, the assembly is only effective when the initial PSD Id that was given to the DFEE showed the P processing flag set. The assembly can be forced by setting the EvtForceProcPE (E7785) DFEE configuration parameter.

4.2.2.4.2.2. Psd Event format

A PSD Event is a fixed format 3-word assembly. The first word gives PSD information and shows several variants, depending on DPE IASW modes and DFEE configuration. The second word gives the AFEE energy. The third word gives the time of occurrence of the first Time Tag in the pair, and the channel number of the AFEE member.

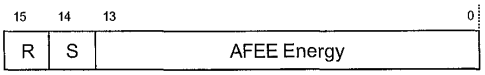
4.2.2.4.2.2.1. Generic PE event format



Generic format of a Psd Event

AFEE Energy format

When not replaced by 0000hex due to time out, the AFEE Energy word shows the usual format :



R : indicates the energy range where "0" = [0KeV .. 2MeV] and "1" = [2MeV .. 8MeV] ;

S : spare bit equals "1" ;

Energy : 14 bits for energy conversion value.

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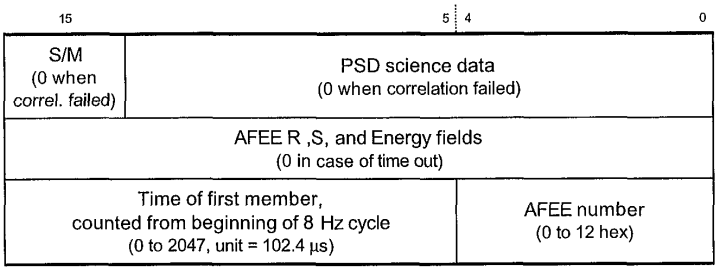
4.2.2.4.2.2.2. Normal PE event format : correlation enabled

In the normal mode of operation, the DPE IASW correlates the table of PE events produced by the DFEE with the list of results produced by the PSD. If the correlation is successful, the result of the PSD pulse shape analysis is incorporated ; otherwise, the PSD information word is set to 0. The resulting PSD event format is the following :



PSD Event format : correlation enabled

S/M : Single/Multiple flag, as defined by the PSD analysis. Equals "1" when the Ge event has been declared as Multiple by the PSD algorithm.

PSD science data : A 15-bit word PSD result summary, obtained by the compression of 3 values. Decompression will be implemented by a post-processing algorithm on ground (see § 4.2.3).

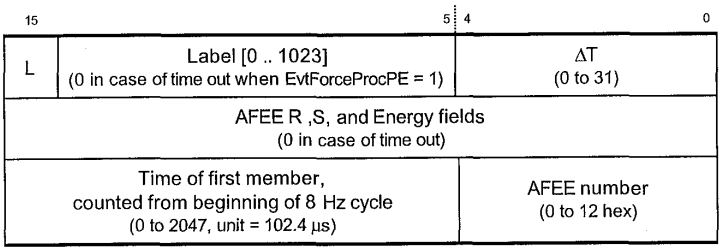
A value of 0 in both the S/M and PSD science data fields indicates that the IASW was not able to make the correlation.

4.2.2.4.2.2.3. **Alternate PE event formats for timing: correlation disabled**

When doing detector timing alignment, the DFEE is configured to provide relative timing information for PE events (EvtSetTimeFmtPE, E7784, is set), and the DPE is configured to disable correlation. Depending on the objective of the alignment, the DFEE configuration and the resulting PE format slightly differ.

PSD detector alignment

When doing PSD detector alignment, the DFEE RouteMode parameter is maintained to its default normal configuration value NoRouting (E7846 = 0). AFEE and PSD assembly may be forced by setting EvtForceProcPE (E7785). In that case, the PE event format is the following :



PSD Event format : correlation disabled, PSD timing

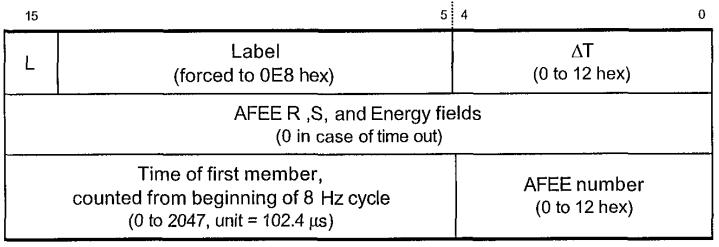
L: sign of ΔT, equals "0" if the PSD Time Tag was observed before the AFEE Time Tag or was simultaneous, equals "1" if the PSD Time Tag was observed after the AFEE Time Tag ;

Label : An increasing, modulo-1024 number transmitted by the PSD to the DFEE in the identifier word after each Time Tag ;

ΔT : absolute value of the duration elapsed between the PSD Time Tag and the AFEE Time Tag, expressed in 50 ns units, in the range [0 .. 31].

AC detector alignment

When doing AC detector alignment, the DFEE RouteMode parameter is set to RouteAcLeft (E7846 = 2). The PSD element actually reflects the timing of the AC gate left edge. Time out is not possible, and the Label field is forced to value 0E8hex. AFEE and PSD assembly must be forced by setting EvtForceProcPE (E7785). In that case, the PE event format is the following :



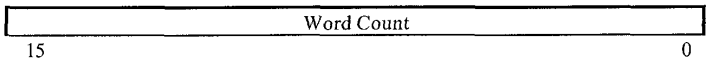
PSD Event format : correlation disabled, AC timing

4.2.2.5. THE PSD CURVES SUB-BLOCK

This sub-block has the following structure

Word N°1	**PSD curve data**
Word N°2	
Word N°i	
Word N°i+1	Number of words in the sub-block excluding itself (WC)

The last word has the following format:



Depending of a configuration parameter sent to the DPE and that enables or disables the correlation of PSD events, the PSD event data has two formats:

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4.2.2.5.1. PSD CURVES WHEN CORRELATION IS ENABLED (NORMAL MODE)

If there is a correlation failure (no corresponding event given by DFEE), the format is the same as format when correlation is disabled (see § 4.2.2.5.2.), so when the word containing R, S and Energy equals 0, that means that either there was a correlation failure, either DFEE didn't receive any energy or identifier value for a detected event.

Bit Number	15	14	13 5	4 0
Event 1	Time			Detector
	R	S	Energy	
	S/M	Science data		
	Curve Data			
Event i	Time			Detector
	R	S	Energy	
	S/M	Science data		
	Curve Data			

R: indicates the energy range where 0=[0KeV..2MeV] and 1=[2MeV..8MeV]

S: spare bit equals "1"

S/M: Single/multiple flag, equals "1" when the event is multiple.

Detector number: identifies the detector chain, ranging from 0 to 12 Hex

Energy: 14 bits for energy conversion value

Time: number of counts from beginning of 8 Hz cycle to event detection (bit weight is 102.4µSec)

Science data: compression of 3 values that will be decompressed by a post-processing algorithm on ground (see § 4.2.3)

Ref. : DSO/ED/DI/SI-138

Curve Data: This is an array of 45 words of 16 bits. Depending on the SPI mode and on configuration parameters of command E310 (curve transmission rates), the curves are downloaded on different rhythms:

- in OPERATIONAL mode, one curve is downloaded each 4 Secs (default value),
- in CALIBRATION and DIAGNOSTIC modes, PSD sends a curve more frequently (maximum of 5 curves per 125mSec by default; the actual number of curves per 125mSec depends on the detector counting rates).

The elementary data is a 9 bits word (9_bW); these 9 bits words are concatenated in 16 bits words format. The following table shows the contents of the 2 first 16 bits words.

16 bits word #0

						Lsbit 0 of 9_b W#1	Msbit 8 of 9_b W#0								Lsbit 0 of 9_b W#0
				Lsbit 0 of 9_b W#3	Msbit 8 of 9_b W#2								Lsbit 0 of 9_b W #2	Msbit 8 of 9_b W #1	

16 bits word #1

The 9 bits words are the results of an analog to digital conversion of the Germanium detector currents. The first 9 bits word (9_bW #0) is the ADC parameter which is an estimate of the event energy obtained by the PSD S/A. This estimate is used by the PSD S/A to decide whether an event should be analysed or not. The remaining 9 bits words (9_bW #1 to 9_bW #79) represent the Germanium detector current as function of time, where each value corresponds to a time step of 10 ns. These 79 values may be plotted in a two-dimensional representation where the x-axis is the number of 9_bW (1 to 79 Dec) and the y-axis is the corresponding 9_bW itself (0 to 511 Dec).

Ref. : DSO/ED/DI/SI-138

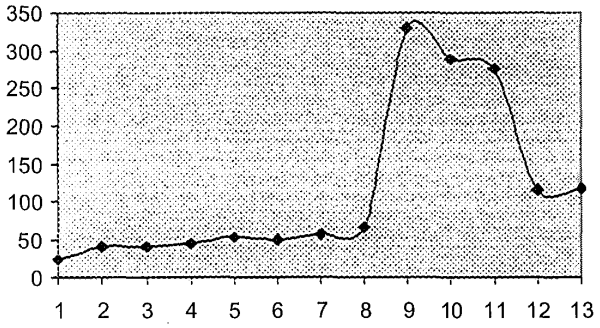
For example, assume that we have these curves data (in hexadecimal):

30 98 48 A4 C2 D1 8C 86 42 1C 86 94 48 A4 4E C7 …

So in binary we obtain:

9_bW # 1 = 24 (dec)							9_bW # 0 = 152 (dec)								
0	0	1	1	0	0		0	1	0	0	1	1	0	0	0
9_bW # 3 = 41 (dec)							9_bW # 2 = 41 (dec)								
0	1	0	0	1			0	0	0	1	0	1	0	0	1
9_bW # 4 = 45 (dec)															
1	1	0		0	0	0	1	0	1	1	0	1		0	0	0	1
9_bW # 6 = 50 (dec)											9_bW # 5 = 54 (dec)				
1		0	0	0	1	1	0	0	1	0		0	0	0	1	1	0
9_bW # 8 = 66 (dec)									9_bW # 7 = 57 (dec)						
0	1	0	0	0	0	1	0		0	0	0	1	1	1	0	0
9_bW # 10 = 289 (dec)							9_bW # 9 = 330 (dec)								
1	0	0	0	0	1		1	0	1	0	0	1	0	1	0	0
9_bW # 11 = 276 (dec)															
0	1	0	0		1	0	0	0	1	0	1	0	0		1	0	0
9_bW # 13 = 118 (dec)											9_bW # 12 = 116 (dec)				
0	1		0	0	1	1	1	0	1	1	0	0	0	1	1	1

This curve must be plotted like this:



Ref. : DSO/ED/DI/SI-138

4.2.2.5.2. PSD CURVES WHEN CORRELATION IS DISABLED

In this case, the PSD curves are downloaded as received by IASW on HSL link. This format is also available when there is a correlation failure due to a lack of a corresponding DFEE event.

Bit Number	15	13 5	4 0
Event 1	P	Label	Detector
	0000		
	S/M	Science data	
	Curve Data		
Event i	P	Label	Detector
	0000		
	S/M	Science data	
	Curve Data		

P: Processing flag, always equals 1 in this case (processed by PSD)

Label: as transmitted by the PSD to the DFEE in the identifier word after each Time Tag

Detector number: identifies the detector chain, ranging from 0 to 12 Hex

S/M: Single/multiple flag, equals "1" when the event is multiple.

Science data: compression of 3 values that will be decompressed by a post-processing algorithm on ground (see § 4.2.3)

Curve Data: as explained before.

4.2.3. Post-processing algorithm of PSD science data

The science data (15 bits word) contained in PSD events and PSD curves represents 3 values (alpha_best, ttp1 and ttp2) that need to be decompressed by a post-processing algorithm on ground.

The proposed decompression algorithm is:

Assume that :

w15 = the 15 least significant bits of science data
w16 = the word containing the S/M flag and the 15 bits of science data
info_minval = 16 (Dec)
info_maxval = 32767 (Dec)
n_templates = value given by Housekeeping command (07X to 09X depending of detector number) (26 by default)

```
if w16 = 0 then
        correlation failure
else
        if w15 < info_minval then
                it is an error code, see the table below
        else
                wgt_alpha = (info_maxval – info_minval - n_templates^2 + 1) / (n_templates^2 x 0.5)
                w = w15 – info_minval
                tmp = [w / n_templates^2] ([ ] means that only the integer part should be taken)
                alpha_best = tmp / wgt_alpha
                ttp2 = [(w – (tmp x n_templates^2)) / n_templates]
                ttp1 = [w - tmp x n_templates^2 – ttp2 x n_templates]
        endif
endif
```

Ref. : DSO/ED/DI/SI-138

For PSD 15-bit words (w15) smaller than info_minval the following error codes are defined. The first column gives the code (lowest 15 bits of the PSD 16-bit word), the second column describes the error, the third column specifies the state of the most significant Bit of the PSD 16-bit word (m=multiple=1, s=single=0).

coded value of w15 (science data)	error meaning	Type S/M
0	No valid library available if S/M flag equals 1 or Correlation failure if S/M flag equals 0	m/s
1	Saturated pulse	m
2	Pulse area too small	m
3	Absolute time-to-peak too early	s
4	Absolute time-to-peak too late	s
5	Baseline too low	s
6	Late pulse starts in baseline	s
7	Early pulse ends in baseline	s
8	Pulse ends too late	s
9	Pulse duration too short	s
10	Pulse duration too long	s
11	Invalid detector	s
12	Pulse area less or equal 0	s
13	Baseline too high	s
14	Baseline outlier	s
15	Pulse area too large	m

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Ref. : DSO/ED/DI/SI-138

4.3. SPECTRA PACKETS

The spectra packets are downloaded in packets with different APIDs according to the SPI current mode:

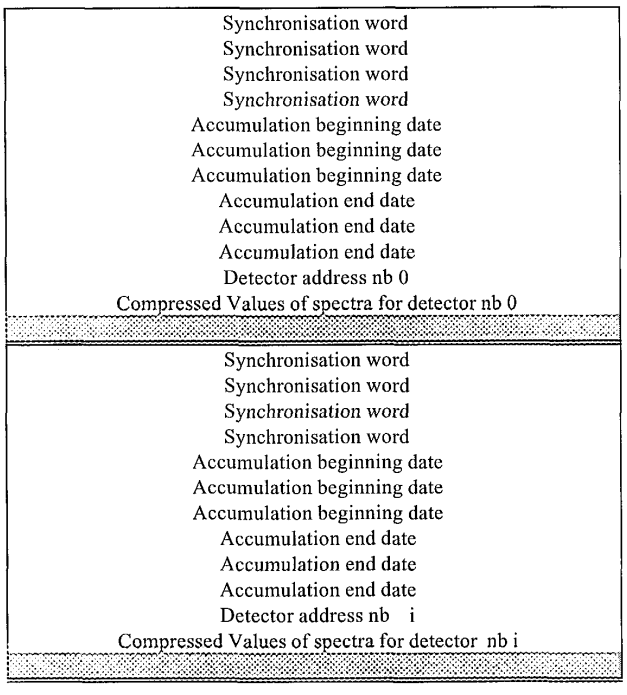
APID is 1104 (1232 R) for OPERATIONAL and DIAGNOSTIC modes (when anticoincidence is off, all events are involved in spectra calculation),

APID is 1105 (1233 R) for EMERGENCY mode (when anticoincidence is on, vetoed events are discarded off spectra calculation).

Nominal APID	SPI mode	Redundant APID
1104	OPERATIONAL	1232
1105	EMERGENCY	1233
NA	CALIBRATION	NA
1104	DIAGNOSTIC	1232

The spectra are accumulated on board during a duration commanded by on board events (Pointing Id, OTF…) and IASW activities (time needed to compress spectra and transmit them to ground). In any case, the actual dates of start and end of accumulation are inserted in the TM packet with the spectra data.

The spectra data is compressed on board using the RICE algorithm. The structure of the spectra data is as described in the following figure:



Ref. : DSO/ED/DI/SI-138

Splitting this spectra flow in 428 bytes TM packets can make the packet edge lie on any byte of any spectrum. Furthermore, the last word of the last spectrum (nb 18) is not necessarily the last word of the packet, so the packet containing the end of the spectrum 18 is paddled with the value 0.

For each detector i, the spectrum is split into eight tables before compression. Each table has a fixed length (before compression):

Table Number	Size of the table (16 bits words)	First channel number of the table	Last channel number of the table	Energy Range (*)
1	4096	0	4095	Low
2	4096	4096	8191	Low
3	4096	8192	12287	Low
4	832	12288	13119	Low
5 See below	4096	13120 (See below)	4497 (see below)	Low / High
6	2432	4498	6929	High
7	4096	6930	11025	High
8	4096	11026	15121	High

The **table 5** contains the last energy channels of the Low range and the first energy channels of the High range, as follows:

Table 5		
Index in the table	Energy channel	Energy Range (*)
0	13120	Low
2879	15999	Low
2880	3282	High
4095	4497	High

This splitting into tables is due to the management of memory by the TLD Ada Compiler System.

(*): In AFEE manual mode (E8943 = 1 in accordance with AFEE corresponding configuration parameters E5070-E5088), the AFEE bit range is ignored by IASW for spectra building and all photon are taken into account in the low energy spectrum.

Ref. : DSO/ED/DI/SI-138

Each table is then compressed on-board using the RICE algorithm. After compression the structure of the compressed spectrum for one detector is as follows (refer to Compressed Values of spectra for detector nb i in above table):

Word Number	Word Contain
0	Number of words after compression for detector i
1	Number of complete words for table 1 detector i
2	Number of bits in last word for table 1 detector i
3	Values of table 1 detector i
j	Values of table 1 detector i
	Number of complete words for table 2 detector i
	Number of bits in last word for table 2 detector i
	Values of table 2 detector i
	Values of table 2 detector i
	Number of complete words for table 8 detector i
	Number of bits in last word for table 8 detector i
	Values of table 8 detector i
k	Values of table 8 detector i

Comments on this table:

- The word number 0 is the number of words after compression for detector i, itself excluded, from the word 1 to the word k, i.e. k.
- The compressed tables have different length, which cannot be known before compression. The compression algorithm generates a flow of bits so the length of the compressed data is not a number of 16

Ref. : DSO/ED/DI/SI-138

bits words. The last word is filled with bits set to 1. The word 1 is the number of complete words and the word 2 is the number of used bits in the last word (word number j).

- If word 2 is different from zero, the length of table 1 after compression is (j-2) = 1 + value of word 1,
- If word 2 equals zero, the length of table 1 after compression is (j-2) = value of word 1,

The compression and decompression algorithm is given in

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The decompressed data are 16 bits words.

The parameters used for Rice compression are the following (cf. CCSDS for the meaning of the parameters):

Number of bits per sample:	16 bits
Number of sample per block:	16 samples
Length of segment	64 blocks
Period of the reference block:	128 blocks

5. DATA GENERATION SEQUENCE

The SPI IASW collects data, formats it in TM packets and sends them in a shared buffer of DPE memory so that CSSW can transmit it to TM at the rate of the Polling Sequence Table. This PST defines the current telemetry share of TM between instruments. To cope with a too low TM rate in case of a higher number of events, the IASW gives different priorities to the various type of data, and applies the adapted algorithm in order to guarantee a continuous observation of housekeeping telemetry; should the lack of TM rate remain, the applied strategy is to discard all new scientific data and the old housekeeping data. This results in a possible time gap between consecutive data packets of the same type.