LAXPC DATA FORMAT

The LAXPC payload consists of three independent instruments with identical operational modes. There are four different modes of operation and each instrument can be operated simultaneously in more than one mode. The purpose of this document is to carry out processing of the LAXPC raw data. Data from different modes of observation will be treated separately.

The LAXPC data carries information about cosmic X-rays detected with the instruments and it has three dimensions: (a) time of detection, (b) energy (spectral channel) of the X-ray photons and (c) identity of the detecting element (detector/anode-layer) including double-identity in some cases. The signals generated by the instrument after detection of X-rays are processed and stored in any of the following four modes. Data stored in each frame of 2048 byte includes the header to identify the system from which data is generated, the Mode ID (MID), the system Time at which data frame was generated, Data Mode (DM), Post Processor ID (PID), the Sub-Mode (SM) and the frame counters.

1. ***Broad Band Counting (BBC) Mode [MID = BC]*:** Records the rate of occurrence of events in various energy bands with selectable bin size (8msec to 1024msec). This frame has one HouseKeeping (HK) and 31 BBC sub-frames. In this mode for HK data MID*(Mode ID)* = BC & DM*(Data Mode)* = 64, indicating 64 bytes data (including 16 bytes of header) for each HK bin period. For BBC header MID = BB & DM = 64, indicating 64 bytes data (including 12 bytes of header) for each BBC bin period. In this mode SM = "00".
2. ***Event Analysis Mode [MID = EA]*:** Identity, Time, and Energy recorded for each event. This mode has a sub-mode where Event Processing Logic (EPL) will operate with ANTI criteria - Bypass (MID = EA, SM=AB) condition, i.e. all ANTI instead of getting rejected will be treated as normal anode.
3. ***Fast Counter Mode [MID = FC]*:** Records the events in two anodes of top layer for energy between 3 to 20keV in 4 different energy bands for fixed bin period of 160µS. In this mode MID = FC & SM = "00".
4. ***Self Test Mode (MID = DD/CD, SM=EA)*:** Each one of the DELI processors and HK processor generates self test data frame on power on as well as by command in case of DELI processors. The MID byte is "DD" indicating self test mode frame. In EP Self Test-Calibration Mode, EP disables all Detector inputs and generates 5 different levels of signals using DAC. During this mode the data will be generated for about 1500 samples at various levels of input voltage between LLD and ULD for 10 anodes. Data will be stored similar to EA mode. In this mode MID = CD & SM = "EA".

Data Frame Formats:

Header: Each of the data frame will have first 16 bytes as a frame header, which includes the package ID (identifying one of the three detectors), mode ID (indicates the data mode: EA/CD/FC/BC/BB), system time stamp, bin period indicating byte, Data Mode byte, processor ID, Sub-Mode ID & data Frame counter.

Table – 1: shows general format for the 16 byte header for LAXPC data frames.

B0	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15
SY	ID	MID	T7	T6	T5	T4	T3	T2	T1	CW	DM	PID	SM	FRCU	FRCL

Details of each header byte:

Header Code	Description	Remark
SY	System Package	DE
ID	Package ID	01 /02 /03
MID	Operation Mode ID	BC for HK data, BB for BBC data, EA for event Data, FC for Fast counter Data, DD/CD for Calibration/Self Test Data.
T7	LAXPC system TIME MSB	LAXPC TIME (56 bits) with 10μS resolution.
T6	LAXPC system TIME LSB + 5	
T5	LAXPC system TIME LSB + 4	
T4	LAXPC system TIME LSB + 3	
T3	LAXPC system TIME LSB + 2	
T2	LAXPC system TIME LSB + 1	
T1	LAXPC system TIME LSB	
CW	Bin Command status word	Lower Nibble indicate the BBC bin period
DM	Data Mode	(05) Indicates the 5 bytes per event for EA mode and for HK/BBC (64) indicates bytes per sub frame
PID	Processor ID	D1 indicates DELI-1 processor and D2 indicates DELI-2 processor, for HK/BBC its "00"
SM	Sub-Mode	In Event Data this byte is "AB", indicating that event data follows is with Anti-criteria Bypass. For all other this byte will be "00"
FRCU	Upper Byte of Frame Counter	Frame Counter (16 Bits)
FRCL	Lower Byte of Frame Counter	

Mode–1 (BBC Mode) **:** In this mode 2K data frame there will have 32 sub-frames of 64 byte each. The 1st sub-frame will have HK data and rest 31 sub-frames will contain BBC data.

Table – 2: shows a typical data frame in MODE–1 (BBC-MODE).

Byte No.	Data Description
B0-B15 (16 Bytes)	Frame Header for Mode-1 (BBC)
B16-B47 (32 Bytes)	House Keeping Data
B48-B63 (16 Bytes)	All "00" as dummy data bytes to complete 64 bytes for a HK sub-frame of Mode-1
B64-B75 (12 Bytes)	Sub Frame Header BBC sub frame of Mode-1
B76-B124 (49 Bytes)	BBC data
B125-B127	3 bytes padding "00" to complete 64 bytes for a BBC sub-frame of Mode–1

B128-B2047 (1984 Bytes)	Similar 30 BBC sub-frames of 64 bytes each.

The first sub-frame of BBC mode has 64 bytes of housekeeping data including its header as shown below:

Table – 2(a): shows typical 16 byte header for **HK sub-frame** of **BBC** data frames.

B0	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15
SY	ID	MID	T7	T6	T5	T4	T3	T2	T1	CW	DM	PID	SM	FRCU	FRCL
DE	01/ 02/ 03	**BC**	T7	T6	T5	T4	T3	T2	T1	CW	**40**	**00**	**00**	FRCU	FRCL

Each sub frame has system 16 byte header, HK data and some dummy bytes to complete 64 bytes of HK sub-frame for MODE–1 frame.

Table – 2(b): The BBC (Housekeeping) Frame Header 16 bytes (B0-B15) are defined as under

Byte Number	**Data Code**	**Description**
B0	SY	System = DE
B1	ID	System (Package) Identification = 01, 02 or 03
B2	MID	Mode ID = BC for Mode 1 (BBC mode)
B3	T7	Time stamp bytes that provide mission time count value with 10 micro second resolution
B4	T6	
B5	T5	
B6	T4	
B7	T3	
B8	T2	
B9	T1	
B10	CW	Bin Control word value of STBG
B11	DM	‘40’ indicating 64 bytes (including 16 bytes header) data of HK BIN.
B12	PID	Processor ID = 00, for HK of BBC Mode
B13	SM	Sub-Mode = 00 for HK of BBC Mode
B14	FRCU	Frame Counter Upper Byte
B15	FRCL	Frame Counter Lower Byte

Table – 2(c): The Housekeeping data bytes (B16-B63) are defined as under

Byte No.	Description
B16	MSB Byte of HV-REF
B17	LSB Byte of HV-REF
B18	MSB Byte of HV-MON
B19	LSB Byte of HV-MON
B20	MSB Byte of LLD1
B21	LSB Byte of LLD1
B22	MSB Byte of LLD2
B23	LSB Byte of LLD2

B24	MSB Byte of LLD3
B25	LSB Byte of LLD3
B26	MSB Byte of LLD4
B27	LSB Byte of LLD4
B28	MSB Byte of LLD5
B29	LSB Byte of LLD5
B30	MSB Byte of LLD6
B31	LSB Byte of LLD6
B32	MSB Byte of LLD7
B33	LSB Byte of LLD7
B34	MSB Byte of ULD
B35	LSB Byte of ULD
B36	MSB Byte of ANTI1
B37	LSB Byte of ANTI1
B38	MSB Byte of ANTI2
B39	LSB Byte of ANTI2
B40	MSB Byte of ANTI3
B41	LSB Byte of ANTI3
B42	MSB Byte of KLLD
B43	LSB Byte of KLLD
B44	MSB Byte of KULD
B45	LSB Byte of KULD
B46	MSB Byte of 80K
B47	LSB Byte of 80K
B48-B63	00

The next 31 sub-frames in MODE–1, each has 64 bytes of BBC data including its header as shown below:

Table – 2(d): Table shows format for the 12 bytes sub-frame header for BBC sub-frame of BBC data.

B0	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
SY	ID	MID	T7	T6	T5	T4	T3	T2	T1	CW	DM
DE	01/ 02/ 03	**BB**	T7	T6	T5	T4	T3	T2	T1	CW	**40**

Each sub frame has system ID, Mode ID, System Time, bin period byte and Overflow flag indicator, BBC data and some dummy bytes to complete 64 bytes of HK sub-frame for MODE–1 frame.

Table – 2(e): BBC (Sub-frame) including Header

B0	DE to indicate start of BBC frame
B1	Package No 01/02/03
B2	BB to indicate start of BBC data
B3	T7

B4	T6
B5	T5
B6	T4
B7	Latched T3
B8	Latched T2
B9	Latched T1
B10	OF flag and Time bin
B11	“40”
B12	LLD-MSB
B13	LLD-LSB
B14	ANTI-MSB
B15	ANTI-LSB
B16	ULD-MSB
B17	ULD-LSB
B18	GE/JE-MSB
B19	GE/JE-LSB
B20	MTO-MSB
B21	MTO-LSB
B22	MTT-MSB
B23	MTT-LSB
B24	NK-MSB
B25	NK-LSB
B26	ANTI-1-MSB
B27	ANTI-1-LSB
B28	ANTI-2-MSB
B29	ANTI-2-LSB
B30	ANTI-3-MSB
B31	ANTI-3-LSB
B32	L1-3-80K-MSB
B33	L1-3-80K-LSB
B34	L1-3-6K-MSB
B35	L1-3-6K-LSB
B36	L1-6-18K-MSB
B37	L1-6-18K-LSB
B38	L2-3-80K-MSB
B39	L2-3-80K-LSB
B40	L3-3-80K-MSB
B41	L3-3-80K-LSB
B42	K1
B43	K2
B44	K3
B45	DK
B46	DEK
B47	L1-18-40K
B48	L1-40-80K
B49	L2-3-6K
B50	L2-6-18K
B51	L2-18-40K
B52	L2-40-80K

B53	L3-3-6K
B54	L3-6-18K
B55	L3-18-40K
B56	L3-40-80K
B57	OF-Flags of cnt16-00 to cnt16-07
B58	OF-Flags of cnt16-08 to cnt16-14 & cnt8-00
B59	OF-Flags of cnt8-01 to cnt16-08
B60	OF-Flags of cnt8-09 to cnt8-14 & '0' & '0'
B61 to B63	Padding with Zero to make 64 bytes sub-frame

Mode–2 (Event mode) :

DELI on power on writes the default 16 bytes of header to its output FIFO. Then at every 2.56ms (on interrupt) transfers the 5 bytes of EPL data to output FIFO (excluding event marker). On encountering the Time marker in EPL data DELI writes Time marker "EF" followed by 4 byte time as "T4,T3,T2 & T1". Thus makes 2K data frames with events data enveloped between time at every 2.56ms (with time marker). If there is no event, then DELI writes only time with marker. If at 2.56ms interrupt, DELI does not find any data (not even T1 roll over time marker) from EPL, i.e. input FIFO is empty then DELI writes 5 byte marker as "EE, EE, EE, EE, EE" followed by 5 bytes of time to indicate that EP is not responding.

Table – 3: Table below shows a typical data frame in MODE–2 (Event MODE).

Byte No.	Data Description
B0-B15 (16 Bytes)	Frame Header for Mode-2
B16-B2047 (2032 Bytes)	Event data (no data error marker) enveloped between TIME data

The frame of MODE–2 has 2048 bytes of Event data including its header as shown below:

Table – 3(a): Table below shows format for the 16 byte header for EA data frames.

B0	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15
SY	ID	MID	T7	T6	T5	T4	T3	T2	T1	CW	DM	PID	SM	FRCU	FRCL
DE	01/ 02/ 03	**EA**	00	00	00	T4	T3	T2	T1	CW	**05**	**D1 / D2**	**AB / 00**	FRCU	FRCL

Each frame has system ID, Mode ID, 7 bytes of System Time, bin period ID, Data mode (5 byte data), Processor ID, Sub-Mode ID & Frame Counter bytes.

In the event mode, the identity, timing and energy of each genuine analysed X-ray event will be stored using 5 bytes (ID, TT, PH1, PH2, PH3). *[ID= UN + LN (where Upper-Nibble = 4bit ID of 2nd event & Lower-Nibble = 4bit ID of 1st event); TT = (event arrival time) lowest byte of (56 bits)* T1 *Time; PH1= Upper 8 bit of 11 bit PHA of 1st event; PH2= Upper 8 bit of 11 bit PHA of 2nd event and PH3 = UN + LN (where Upper-Nibble = Lower 3 bits of 11 bit PHA + K flag of 2nd event & Lower-Nibble = Lower 3 bits of 11 bit PHA + K flag of 1st event)]*. For all practical purpose (data analysis) we will be using only 10 MSB bits of PHA of each event.

For example:

1) If there is a single genuine event say at time T1=2C on Anode–4 and 12 bit PHA is say 1F8 and as its not K-band event i.e. K1-flag is not set. Then typical data will be.

04	2C	1F	00	08

2) If there is a simultaneous two genuine events say at time T1=33 on Anode–2 & Anode–6 and 12 bit PHA for Anode-2 (we treat as 1st event) is say 5E0 (in K-energy band, i.e K1 flag set) and PHA for Anode-6 (we treat as 2nd event) is say 235 (as its not K-band event i.e. K2-flag is not set). Then typical data will be.

62	33	5E	23	41

Her PH3 LSB bit indicate the K1 flag, while the bit-5 from LSB is 0 to indicate K2 flag not-set.

At every 2.56 msec the event data will be enveloped by "EF, T4,T3,T2, T1" time stamps as 5 bytes system time. Since event rates for LAXPC can vary over a wide range, the separation between successive time stamps will vary and the time stamps are inserted into the data frame with a unique one byte marker. Though the location of the time stamps will not be fixed, there will be same number of time stamps per unit of time. For example, if event rate is low, like < 400 events/sec, there will be very few events data (0, 5, 10 or 15 bytes) between successive time stamps. Whereas, if the event rate is high, like 20,000 events/sec then the time stamps will be separated by about 250 bytes.

Example: For normal Event mode data typical data frame format will be as
[16 bytes header], "ID, TT, PH1, PH2, PH3", (one event within 2.56ms time) "EF, T4, T3, T2, T1", "ID, TT, PH1, PH2, PH3", "ID, TT, PH1, PH2, PH3", (two events within 2.56ms time) "EF, T4, T3, T2, T1", (no events within 2.56ms time) "EF, T4, T3, T2, T1" and so on … till 2046bytes and then two 'EE' 'EE' as frame end marker.

If during normal event mode operation, a change of mode command is received then the typical data frame will be : [16 bytes header], "EF, T4, T3, T2, T1", "ID, TT, PH1, PH2, PH3", "EF, T4, T3, T2, T1", … until new mode command, and then "EE, 00, 00, 00, 00" and so on… till frame end i.e. 2K bytes are over.

Each frame of 2048 bytes will start with a 16 byte header. A minimum of one event frame will be generated every 1.04 seconds. In case HV is OFF and no event data is generated, then entire frame will be filled with 5 byte time markers only, at every 2.56 msec, this translates into 406 time stamps in one frame or 406 x 2.56 msec = 1.039 seconds.

Table – 3(b): Table below shows a typical data frame in Mode–2 (5 Bytes).

Byte No.	Data contained
B0-B15 (16 Bytes)	Frame Header (MID=**EA**, DM=05 SM=**00**)
B16-B2045 (2030 Bytes)	Time Tagged Event data enveloped within Time Markers (5 Byte each)
B2046-B2047 (2 Bytes)	Frame End padding Byte (EE)

Mode–2 (Event Mode- Anti-criteria Bypass (AB)): In this sub-mode EPL operates in ANTI-criteria-Bypass (AB) mode. Thus instead of rejecting any ANTI pulse, it will be treated same as main anode. Hence even for ANTI event there will be 5 byte data from EPL.

Table – 3(b): Table below shows a typical data frame in Mode–2 (AB) (5 Bytes).

Byte No.	Data contained
B0-B15 (16 Bytes)	Frame Header (MID = **EA**, DM=05, SM=**AB**)
B16-B2045 (2030 Bytes)	Time Tagged Event data enveloped within Time Markers (5 Bytes each)
B2046-B2047 (2 Bytes)	Frame End padding Byte (EE)

Mode-3 (Fast Counter (FC) Mode) **:** In this mod, the events data for two anodes of top layer for energy between 3 to 20keV in 4 different energy band for fix bin period of 160μS are produced. Thus 5 bytes are written at every 160μs to output FIFO. This mode has DM = 05 indicating 5 bytes data for each bin period.

Table – 4: Table below shows a typical data frame in Mode–3 (FC – 5 Bytes)

Byte No.	Data contained
B0-B15 (16 Bytes)	Frame Header (MID = **FC**, DM=05, SM=**00**)
B16-B2045 (2032 Bytes)	Fast Counter (FC) data (5 bytes each)
B2046-B2047 (2 Bytes)	Frame End padding Byte (EE)

Example: For normal FC mode data typical data frame format will be as
[16 bytes header], "FC, DT1, DT2, DT3, DT4", and so on … till 2K bytes.

If during normal event mode operation, a change of mode command is received then the typical data frame will be : [16 bytes header], "FC, DT1, DT2, DT3, DT4" ... until new mode, and then "EE, 00, 00, 00, 00" and so on … till 2K bytes.

Mode-4 (Self Test (DD) / Self Calibration (CD)) **:** Each one of the DELI processors and HK processor generates self test data frame on power on, as well as by command in case of DELI processors. The MID byte for self test frame is "DD" indicating self test mode frame. In case of EP processor when, self calibration mode is invoked by command, EP stops receiving the pulses from detector and generates input signal using an internal DAC for 5 different signal levels. During this mode the data will be generated for about 1500 samples at various level of input voltage between LLD and ULD (about 507mV, 1.02V, 2V, 3.1V, 4.98V & 7.49V) for 10 anodes. During each sample, signal will pass through same channel path of EPL as that of detector event signal. Thus EPL will generate similar data and event counting pulses, as it produce for detector event mode.

Table – 5: Table below shows a typical data frame in Mode–4 (DD/CD) (5 Bytes).

Byte No.	Data contained
B0-B15 (16 Bytes)	Frame Header (MID = CD/DD, DM=05, SM=**EA**)
B16-B2045 (2030 Bytes)	Time Tagged Event data enveloped within Time Markers (5 Bytes each)
B2046-B2047 (2 Bytes)	Frame End padding Byte (EE)

Before changing to new pattern or mode of data old data frame will be flushed, i.e. the current data frame will be padded with "EE, 00, 00, 00, 00".