LET Science Data Frame Format

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1.0 Introduction

The purpose of this document is to describe the science data that will be transferred from the LET MISC to the SEP Central MISC. The format does not describe beacon data, nor does it describe CCSDS packet header or checksum information.

This document makes reference to information in the following external documents:

- LET Science Requirements Document
- *STEREO SEP LET and SEP Central: Flight Software Requirements* (*Version F, STEREO-CIT-002.F*)
- *STEREO IMPACT SEP Sensor Suite Commanding and Users Manual* (*Version F, STEREO-CIT-007.F*)
- *Specification of Functional Test Modules and In-flight Calibration Routines for LET* (*STEREO-CIT-006.A*)
- *STEREO/IMPACT LET Detector Naming* (*STEREO-CIT-0015.B*).
- *LET Software Counter Definitions* (*STEREO-CIT-019.A*).
- Interface Control Document (ICD) for the IMPACT Investigation.
- CCSDS 102.0-B-5 Packet Telemetry, Blue Book, Issue 5

Information is also included from other documents, memos, e-mail messages, discussion not in the formal STEREO/IMPACT document collection. Elements to be resolved or to be determined, or elements documented only in software, are marked **TBD.**

In this document, “LET Science Frame” and “LET Science Data Frame” may be used interchangeably.

2.0 LET Science Data Frame Format -- Requirements and Goals

The LET Science Data Frame Format is designed to accommodate the following LET Science requirements and goals, abstracted from the LET Science Requirements Document:

Table 1.1: Selected LET Science Requirements and Goals

	Requirements	**Goals**
Event (Pulse Height) Telemetry Rate	1 event/sec with prioritization	~4 events/sec with prioritization
Species Coverage (rates data)	10 species (H, 3He, 4He, C, N, O, Ne, Mg, Si, Fe)	16 species (H, 3He, 4He, C, N, O, Ne, Na, Mg, Al, Si, S, Ar, Ca, Fe, Ni)
Energy bins (rates data)	3 intervals for H 6 intervals for $Z \geq 2$	multiple energy bins, depending on species and penetration range
Event processing rate (rates data)	1000 events/sec	~5000 events/sec
Telemetry interval (time resolution) for rates data	15 minutes for all species	1 minute for all species

The LET Science Data Frame Format as described in this document will attempt to accommodate the rates-related <u>Goals</u> listed in Table 1.1.

The LET Science Data Frame Format is also designed with the following software engineering goals as guidance:

- Maximize bandwidth usage (i.e. minimize number of unused bits)
- Maximize event data (pulse height) bandwidth allocation
- Align data elements to nibble (4-bit) boundaries, byte boundaries, or MISC word (24-bit) boundaries, to simplify data examination in hexadecimal format
- Send data at short, regular intervals to the SEP Central MISC, to allow for faster debugging.
- In the event of bit errors (expected to be extremely rare), event data should be as reconstructible as possible to reduce the fraction of corrupted event data.

LET is allocated 16 CCSDS packets per minute, out of the 36 CCSDS packets per minute allocated to SEP. The 11 byte header and 1 byte checksum for each 272 byte CCSDS packet are not included in the LET Science Data Frame Format. Therefore, one minute of LET Science Data corresponds to 16*260 = 4160 bytes. Define these 16 CCSDS packets (minus headers and checksums) as one LET Science Data Frame, for transmission from LET to the SEP Central MISC. The goal is to accumulate and transmit all science rates (species counts) in one minute intervals, so that each LET Science Data Frame contains a complete set of science rates for a given minute.

According to the *SEP LET and Central MISC Processors Flight Software Requirements* document (Version E), the LET MISC will have opportunities to transmit complete CCSDS packets (with headers and checksum) to the SEP Central MISC once every three seconds. It is left to the SEP Central MISC to fill in time stamps and checksums in the CCSDS packets before passing them to the IDPU. The LET MISC will fill in ApIDs and source sequence counters and other pack identification information. A complete LET Science Frame is transmitted each minute, with rates and pulse heights having been packed into the Science Frame format and divided into CCSDS packets during the previous minute. If the event buffer (Section 2.8) does not get filled to the point of requiring the full 4160 byte allocation of the LET Science Frame, the LET MISC will fill the remaining packets with 0's.

The flow of data from LET to the IDPU is represented graphically in Figure 1.1.

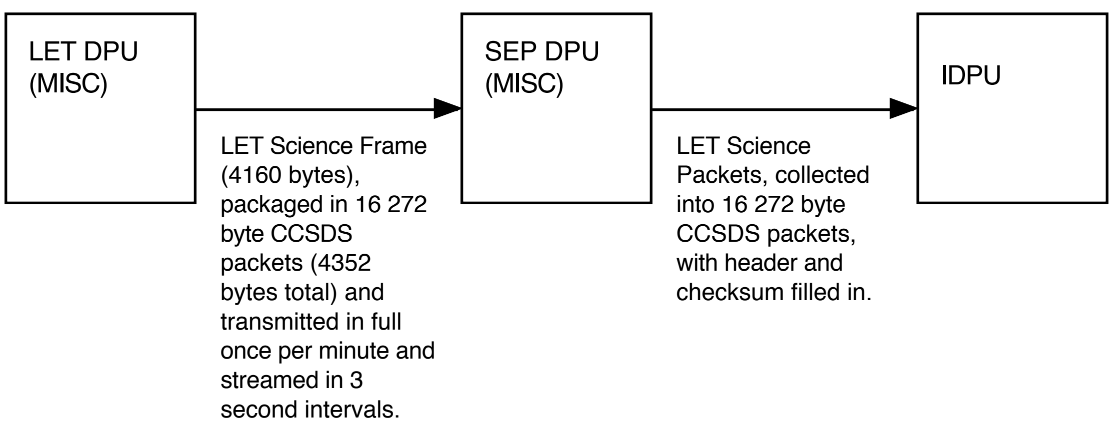
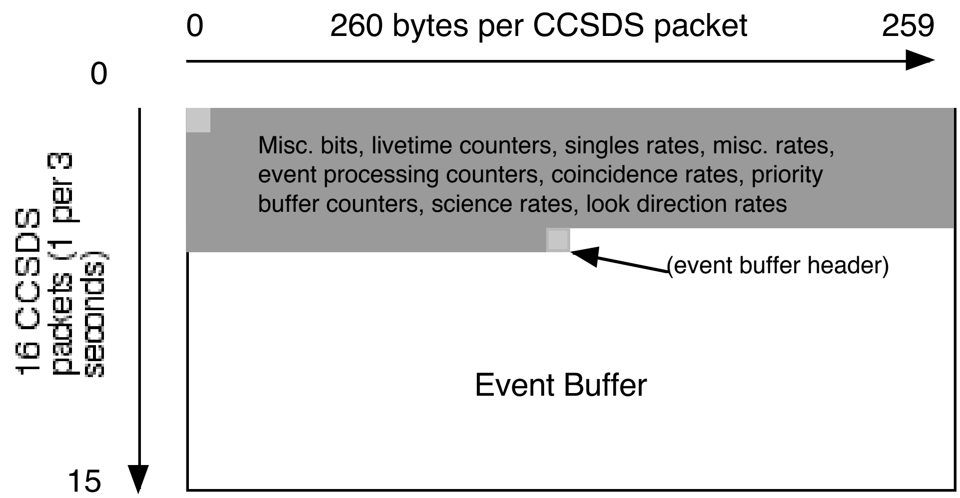
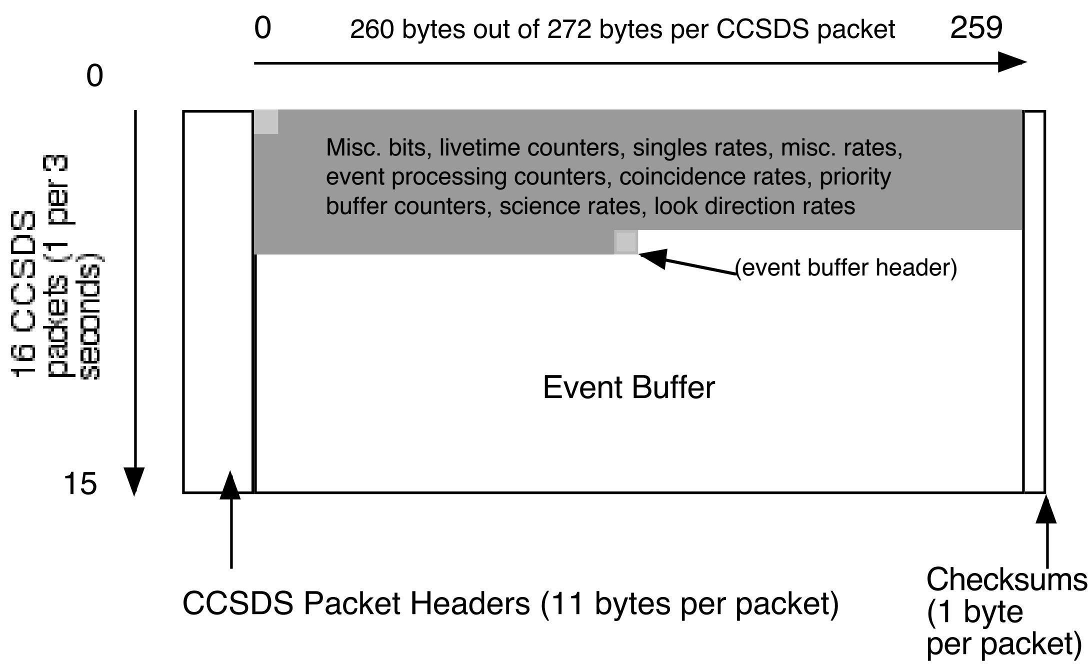


Figure 1.1: Data flow from LET to IDPU



(a)



(b)

Figure 1.2: LET Science Frame Overview, (a) without CCSDS packet headers and checksums, and (b) with CCSDS packet headers and checksums. LET Science Frame Header is unlabeled at upper left. (Data elements not to horizontal scale.)

A LET Science Frame is shown graphically in Figure 1.2, with and without CCSDS packet headers and checksums. It includes 16 CCSDS packets for a total of 4160 bytes (not including CCSDS packet headers and checksums). Rates data occupy ~5.5 CCSDS packets. Event data occupy the remaining CCSDS packets.

Note that, although LET will be transmitting one science data packet every three seconds, only the first 16 of those packets will comprise a science frame. Within the science frame, unused event buffer space will be filled with 0's. The spare frames will also be filled with 0's and assigned a unique ApID.

2.1 Byte Order

The LET Science Frame is envisioned as an array of bytes or as a stream of bytes. Transmission of data elements is also envisioned as a stream of bytes. When a LET Science Frame element spans more than one byte, it will be transmitted high-byte-first. For example, Event Buffer Headers (Section 2.8) span four bytes, or one MISC word plus one byte, and these will be transmitted in the order of highest byte, second high byte, second low byte, and lowest byte.

2.2 ApID and Packet Number

The ApID value of 580 is assigned to every LET Science Frame Packet, and this value is stored in the CCSDS packet header (not part of the LET Science Frame itself). In order to identify individual packets within the LET Science Frame, bits 0–3 of the subseconds field of the CCSDS packet header are replaced by a packet number. The packet numbers are defined in Table 2.1, as also shown in Figure 1.2.

Table 2.1: LET Science Packet Numbers

Packet #	Packet Description
0–4	Science Frame Header, Counters and Rates
5	Counters and Rates, start of Event Buffer
6-15	Event Buffer frames

The ApID and packet numbers will be assigned by the LET MISC and entered into each CCSDS packet header. The LET Science Data Frame does not make direct use of the source sequence counter in each CCSDS packet header.

2.3 LET Science Frame Header

Some header information is included in the CCSDS packet headers (secondary headers). However, because CCSDS packet formatting may be removed during ground-based analysis in order to extract full LET Science data from each set of LET CCSDS packets, it will be useful to include a LET Science Frame Header.

The LET Science Frame Header is allocated as 5 bytes at the top of the LET Science Frame. Byte 0 is the spacecraft ID (SCID) and frame version number (SFVER). The two most significant bits are the spacecraft ID — 00 for the EM unit (no spacecraft), 01 for FM1 (the leading spacecraft, or "ahead"), and 10 for FM2 (the trailing spacecraft, or "behind"). The remaning bits are a LET Science Frame Version number; the current version number is 11. Should the version number ever exceed 128, the version number in these bits will be calculated modulo 128.

Bytes 1 and 2 (high byte and low byte – see Section 2.1) contain the number of valid bytes (SFLEN) in the complete LET Science Frame (not including CCSDS header and checksum). “Valid” bytes include all the bytes from the frame header to the last byte of the last event in the event buffer, and this counter does not include CCSDS packet headers or checksums. Because 6 CCSDS packets containing fixed format data are always present, this number is never less than 1418. This number never exceeds 4160. The three most significant bits of byte 1 are unused.

The last two bytes (bytes 3-4) of the LET Science Frame Header are defined as a checksum (SFCHECK, to verify the integrity of the LET Science Frame Data. The checksum algorithm is **TBD**. It is proposed that the two bytes be set such that the sum of all bytes or MISC words modulo 2^{16} equal zero. Individual bytes are summed, with the checksum allowed to grow to 16 bits. This checksum is independent of the CCSDS packet checksums and is calculated by the LET MISC prior to the calculation of CCSDS packet checksums by SEP Central.

The contents of the LET Science Frame Header are summarized in Section 3.0.

2.4 Science rates (species counts, rate counters):

For the science rates coming with each frame, counts for H and He (He-3 and He-4), 13 heavy elements (C, N, O, Ne, Na, Mg, Al, Si, S, Ar, Ca, Fe, and Ni), and various "background" counts (including charge ranges) will be transmitted. Science Rates will be organized top–down in order of penetration range, then species, then energy. Science rates included in the LET Science Frame are summarized in Tables 3.9–3.14, and their locations in the LET Science Frame are detailed in the same tables.

As described in the *STEREO SEP LET and SEP Central Flight Software Requirements (Version F, STEREO–CIT–002.F)* document, particles which pass certain onboard processing cuts are sorted into matrices according to their penetration range in the instrument and by delta–E vs. E' measurements. Each matrix represents a penetration range — into the L2 detectors (RNG2, or L1L2), into one L3 detector (RNG3, or L2L3), or into two L3 detectors and possibly beyond (RNG4, PEN, or L3AL3B). Within each penetration range, the associated matrix covers a delta–E vs. E' space that spans particles from Z=1 (H) to Z≥40 (Zr). The matrices are used by onboard processing to identify particles by range in the instrument and charge, and further onboard processing is used to determine particle kinetic energy. The matrices span 128 bins in the x–axis and 400 bins in the y–axis, and they are shown graphically in Appendix C. (Note that this LET Matrix information supercedes details in *STEREO–CIT–002.F, Appendix 1*, which is out of date as of this version of the LET Science Data Format.)

Particles that are sorted through the matrices are counted in arrays in the LET onboard memory, sorted by penetration range, species (element, charge, charge range, or background), and energy (for elements). Particle counting rates with defined element and energy are termed "foreground rates" (FGRATES), following the curved tracks bounding elements in the Figures in Appendix C. Foreground rates include elements (and helium isotopes) such as H, He-3, He-4, C, N, O, Ne, Na, Mg, Al, Si, Ar, Ca, Fe, and Ni. Particles counted by the FGRATES are assigned Particle IDs which equal their index values in the FGRATES arrays associated with each penetration range (L1L2=L2FGRATES, L2L3=L3FGRATES, L3AL3B=PENFGRATES). These Particle IDs are also used to identify particles in the Event Record Headers, described in Section 2.8. The Particle IDs are given in Tables 3.9–3.14. Particles not located in the FGRATES regions of the matrices, or particles which are otherwise unclassified by the matrices, are assigned a Particle ID of 255. Note that some elements are classified by the Range 3 matrix but not in the other matrices. These particles are also assigned a Particle ID of 255 when located in the Range 2 or Range 4 matrices, e.g. Na in RNG 2 and RNG 4.

Particle IDs may be duplicated between different ranges. While it may be convenient for science analysis for particles having the same charge and energy range in two different matrices to have the same Particle ID, it would add additional load to limited onboard computing resources. It will be less strain on computing resources to account for different Particle IDs during analysis on the ground.

Particles in the matrices which do not fall along element or isotope tracks are termed "background rates" (BGRATES). Background rates are counts from broad regions of delta–E vs E' space in the matrices such as the Li, Be, and B region between He and C, or the "backward moving particles" region to the lower right corner of delta–E vs. E' plots. The background rates also include regions covering STIM events, described elsewhere. All background rate events are assigned Particle ID 255. The background rates are summarized in Tables 3.9–3.14.

Finally, science rate counters are stored in onboard memory in 24 bit counters, but in the Science Frame, these rates are compressed to 16 bits. The format for the compressed, 16 bit rates is shown in Figure 2.1.

exponent E (4 bits)				mantissa M (12 bits)											
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Figure 2.1: 16 bit compressed rate.

The compression algorithm will be a 16 bit modified biased exponent hidden one algorithm, as detailed in Appendix A.

Thus, there are currently 371 Science Rates in the LET Science Data Frame, for a total of 742 bytes.

2.5 Look Direction Rates

Under the current LET Science Frame Format, 8 look directions toward the A side of the LET detector and 8 look directions toward the B side of LET will be counted, for 10 rates in each direction. A total of 160 look direction rates will be encoded in the LET Science Frame. Each look direction rate will be encoded in 16 bit compressed rates, using the same format and compression/decompression algorithm as the science rates. Thus, we send a total of 320 bytes of look direction rates per LET Science Frame.

The look directions are divided into 8 sectors on either side of LET, with detector combinations currently described elsewhere. (See *Options for LET Sectored Rates* and *Final Selection of Sectored Rates (9/29/03)* memos (R.A. Mewaldt).*)* For the purpose of the LET Science Frame Format, the 8 sectors are numbered 0 through 7, and they are geometrically arranged clockwise around the LET detector, so that sector 0 of LET side A is associated with the L1A0 detector, and sector 7 of LET side A is associated with the L1A4 detector. (See *STEREO/IMPACT LET Detector Naming, STEREO-CIT-0015.B*.) Numbering on the B side begins with direction 8, so that sector 8 of LET side B is associated with the L1B0 detector, and so on.

In addition to look directions, or sectors, these rates are divided into element or element ranges: H, He–3, He-4, CNO, NeMgSi, and Fe. Within each element, these rates are further divided into energy ranges.

Organization of the look direction rates arranged top–down by species, energy range, and look direction, with look direction first on side A (directions 0 through 7) and then side B (directions 8 through 15). The look direction rates are summarized in Section 3, Table 3.15:

2.6 Singles and Coincidence Rates

There are 54 ADCs in LET, and each ADC will be measured for singles rates at low and high gain thresholds. These rates will be compressed to 16 bits, using the same compression/decompression algorithm employed for science and look direction rates. Thus, there will be a total of 108 singles rates in the LET Science Frame, for a total of 216 bytes. The singles rates are given in order of detector address number, which is used by the LET onboard software for detector addressing. The ordering of singles rates in the LET Science Format is top–down by detector number, then by high gain and low gain. Thus, the first four bytes in the Singles Rates block are L2A0 (detector address 0), with the first two bytes being L2A0 high gain singles rate, and the second two bytes being L2A0 low gain singles rate. (Furthermore, given the byte ordering described in Section 2.1, the first byte of the L2A0 high gain singles rate is the high byte, and the second byte is the low byte.) See Section 3, Table 3.4 for a summary of the singles rates and their location in the LET Science Frame, and see the *LET Detector Naming* Document for a description of the detector naming convention.

Coincidence rates are listed in Section 3, Table 3.7. These rates count coincident hits for detector groups for the minute spanned by the Science Frame. Space in the LET Science Frame is allocated for 12 coincidence rates (including 2 unused spares), compressed to 16 bits as with other rates.

2.7 Livetimes, Event Processing Counters, and Priority Buffer Counters

Space is allocated in the LET Science Frame for livetime counters, event processing counters, and priority buffer counters. These counters are event or processing counts used or otherwise maintained by the LET onboard software, and they are partially described in *LET Software Counter Definitions* (*STEREO-CIT-019.A*) and in no other formal STEREO/LET Documents. These counters should be formally described in the LET Documentation — **TBD**. The use of the livetimes to calculate intensities should also be formally described.

LET Livetimes, event processing counters, and priority buffer counters are listed in Section 3, Tables 3.3, 3.6, and 3.8, respectively. All of the counters are stored as 24 bit numbers in the LET onboard memory, and in the LET Science Format, they are compressed to 16 bits using the same compression algorithm as is used with the science rates. The one exception is the Front End Electronics livetime counter (bytes 8–7 in the LET Science Frame), which is scaled from 24 bits to 16 bits.

Notes on Table 3.3: The NUMTRIG, NUMREJECT, etc. counters are hardware counters, with counters for events taken under hazard (.HAZ) conditions. NUMTRIG is the number of trigger events detected by the hardware during every even numbered second during the minute of accumulation time for the science frame. NUMREJECT is the number of trigger events rejected for further analysis, as determined by hardware conditions described elsewhere. NUMACCPHA is the number of trigger events accepted for further analysis with PHA data, as determined by the hardware. NUMACCNPHA is the number of trigger events accepted for further analysis without PHA data; however, since all accepted events currently include PHA data, this number is always zero. Under the current definitions, the sum of NUMREJECT and NUMACCPHA should equal NUMTRIG. Because these counters are accumulated only during even numbered seconds, they represent only half the total number of triggers, etc. which could be detected during the entire minute

The equivalent .HAZ counts are those counted under hazard conditions, and these are accumulated during odd numbered seconds during the minute. A trigger event is flagged as a .HAZ event if it comes within 18/6.4 (~2.8) microseconds after the previous trigger. The .HAZ condition is an added condition to the trigger logic; it is not exclusive. Therefore, if NUMTRIG and NUMTRIG.HAZ events were counted simultaneously, the NUMTRIG.HAZ events would count a subset of the NUMTRIG events. The NUMREJECT.HAZ and NUMACCPHA.HAZ events are defined as NUMREJECT and NUMACCPHA events, only with the .HAZ condition added. As with non-.HAZ events, the .HAZ events represent only half the total number of .HAZ events which could occur during a given minute, since they are accumulated only during odd numbered seconds.

Currently, all .HAZ events are rejected for analysis, though this rejection can be commanded on or off. The livetime counter is not incremented during .HAZ events, when such events are rejected for analysis.

2.8 Miscellaneous Bits and Rates — TBD

Some information regarding the state of the instrument and software, as well as rates not defined in previous sections, are allocated space in the LET Science Frame. Two bytes of MISCBITS and 10 bytes of MISCRATES are allocated to the LET Science Frame, and these bits and bytes are located in the Frame in Section 3, Tables 3.2 and 3.5. MISCBITS contain information via software flags on the state of the instrument and a minute counter; MISCRATES are currently **TBD**.

2.9 Event Buffer – Event Record Format:

With the fixed format data described in previous sections for the LET Science Frame, there remain 2733 bytes, all of which will be pulse height data in an Event Buffer. Events (pulse heights) are sampled by the LET MISC from priority buffers listed in Section 3, Table 3.8 and described in separate documentation (**TBD**), and the sampled pulse heights are packaged into Event Records in the Event Buffer. The telemetered events will not exceed the Event Buffer length.

At the top of the event buffer will be a header containing the number of events saved to the buffer. If the minimum event length of 2 ADC hits is 72 bits (9 bytes – see below), then the event buffer can contain up to ~303 events, with one 2 byte event buffer header. Unused buffer space will be filled with $00's, and empty packets will not be transmitted.

Within the buffer, each event should be collected in a defined event record, composed of an Event Record Header (ERH) followed by a variable number of ADC fields. The 32 bit Event Record Header is defined as follows:

Table 2.2: Event Record Header (ERH)

Data	**Bit**	**Note**
Particle ID	0–7	= particle ID if the particles are sorted by the LET Matrices as “foreground” particles. (=255 if the particles are not sorted by the matrices or are identified as background particles). Allows matrices to ID particles by range (matrix), species, and energy. See Section 3, Tables 3.9–3.14 for lists of Particle IDs. See also *SEP LET and Central MISC Processors Flight Software Requirements* (*STEREO-CIT-CIT-002.F*).
Priority Buffer Number	8–12	See Section 3, Table 3.8 for a list of Priority Buffer Numbers and their descriptions. See also *LET Software Counter Definitions* (*STEREO-CIT-019.A*), and uncatalogued memos by RAM (**TBD**).
L1A Tag	13	Indicates an L1A detector contributed to the coincidence trigger
L2A Tag	14	
L3A Tag	15	
L1B Tag	16	
L2B Tag	17	
L3B Tag	18	
STIM Tag	19	Flags a STIM event.
HAZ Tag	20	Hazard flag.
Latency Bits	21–24	Duplicates the 4 least significant bits of the LET onboard minutes counter (Section 2.8, and Table 3.2); used to identify event latency
A/B Event Tag	25	A=0, B=1
# Unread ADCs	26–28	# hit ADCs not include in the Event Record. Saturates at 7.
Extended Header Flag	29	=1 if an additional header byte (or set of bytes) is appended to this header (**TBD**)
STIM Block Flag	30	=1 if STIM Information Block is included in this event
Culling Flag	31	=1 if number of ADCs culled from this event is nonzero.

The format of the event record header is summarized in Figure 2.2:

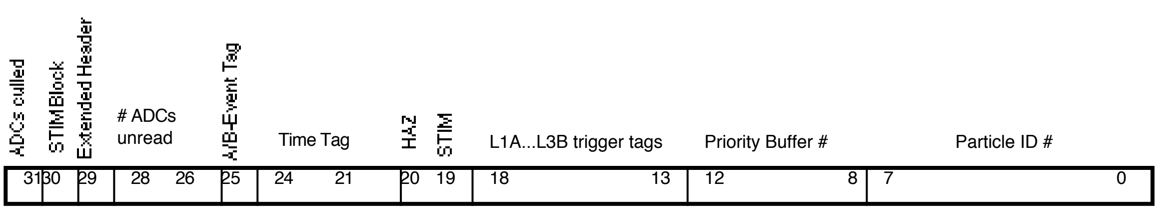


Figure 2.2: Event Record Header, 32 bits.

The particle ID identifies the particle by species and energy, based on how it was sorted through the LET Matrices (Section 3, Tables 3.9–3.14, and Appendix C). If the particle is not a “foreground” event (i.e. if it is not identified as a selected element or helium isotope for a given matrix) and is instead a “background” event, or if the particle is not sorted by the LET matrices, it is assigned a Particle ID of 255. For the identifiable elements targeted by the LET instrument (Table 1.1), the Particle ID is sufficient to identify element and energy.

Additional information is provided by the priority buffer number (bits 8–12). This number identifies the priority buffer from which the Event is taken. Although all events in the Event Buffer are taken from the Priority Buffers, not all events are sorted by the LET Matrices. Not all particles which trigger the LET instrument enter the Priority Buffers. Instead, a sample of trigger events is sent to the

Priority Buffers, which are defined and weighted to target particle types according to the goals of the LET instrument. Priority Buffers (listed in Table 3.8 and described in detail elsewhere — **TBD**) are defined to identify classes of particles by penetration range, by charge or charge range, or by other characteristic (e.g. STIM events). There is some overlap in information between Particle ID and Priority Buffer number. The Priority Buffer definitions and the filling and extracting methods are described elsewhere (**TBD**). See Section 3, Table 3.8 for a list of Priority Buffer numbers.

The L1A through L3B trigger tags identify which detector groups were involved in the trigger conditions, and the A/B tag identifies which side of the detector provided the trigger. The HAZ flag marks a hazard condition **TBD**. The STIM flag marks a calibration event defined in *Specification of Functional Test Modules and In-flight Calibration Routines for LET, STEREO-CIT-006.A*. STIM events follow a special format, described in Section 2.10.

The Latency Bits duplicate the four least significant bits of the minutes field of an onboard clock (LET internal minute counter), as an indicator of event latency. When events are packaged and placed in priority buffers, these minutes bits are copied onto the ERH Latency Bits. Later, when the full Science Frame is packaged into CCSDS packets, the time of the assembly of the Science Frame is copied onto time fields in the CCSDS packet headers and onto the Minutes counter of MISCBITS (Section 2.8, and Table 3.2). Because the time that an event is popped off its priority buffer and placed into the Science Frame may be delayed by more than one minute after the event is first pushed onto the priority buffer, the Latency Bits for a given event may not correspond to the time that the event's Science Frame is assembled. It is up to the user of the data to determine what value of the latency bits precisely corresponds to times associated with given Science Frames. (Note: Previous versions of this document identified the Latency Bits – or Time Tag bits – as counting the age of the event, in minutes, relative to its Science Frame. Also, because the Latency Bits are the 4 least significant bits of a minutes field in a clock, the value of the Latency Bits cycles from 0 to 15 three times, followed by 0 to 11, over the course of an hour.)

For some classes of events, large numbers of detectors or ADCs in the LET instrument may be triggered and result in signals. The LET Data Format (Event Record Format) described herein is capable of returning events with the maximum of 54 ADC hits. Most of these events are unlikely to be sorted by the LET Matrices, but some fraction of them will be sent to the Event Buffer. For events with sufficiently large numbers of hit ADCs, not all ADCs will be included in the Event Record. The onboard software will determine the maximum number of ADC signals transmitted for each event (**TBD**). Bits 25–27 will count the number of ADCs in the event which are **not** included in the Event Record, with a saturation value of 7.

A separate number counting the ADCs **included** in the Event Record is not included in the Event Record Header. Instead, and End of Record (EOR) bit is employed in the ADC Field, described later in this section. Furthermore, LET has a VERBOSE mode in which both low gain and high gain signals from a given ADC may be transmitted. By relying on the EOR bit in the ADC Fields, the format allows for transmission of low and high gain signals for any given ADC, and the EOR bit itself is sufficient to mark the length of an Event Record.

An Extended Header flag (bit 29) marks the addition 2 bytes of header information, described in Section 2.11. A STIM block flag (bit 30) marks the addition 2 bytes of STIM block information to the header, described in Section 2.10. A final ADC culling flag (bit 31) marks the condition that one or more ADCs were culled by onboard software for the event. If culling mode is off, this bit is always zero.

Following the header are a number of ADC fields. Each ADC field will contain the following:

Table 2.3: ADC Field — Minimum Bit Allocations

Data	# Bits	Note
ADC Signal	12	11 bits signal, 1 bit overflow
ADC/Detector ID	6	54 detectors maximum
Low/High gain	1	0 = low gain, 1 = high gain
Last hit flag (End of Record, EOR)	1	Set to 1 for the last ADC in an event, 0 for all other ADCs

Thus, each ADC signal and identifier is encoded in 20 bits. Note that the End of Record (EOR) bit is 0 except when set to 1 for the last ADC Field in an event record. The detector ID is the same as the detector address, a list of which can be found with the singles rates table, Section 3, Table 3.4. The format of the ADC Field is given in Figure 2.3:

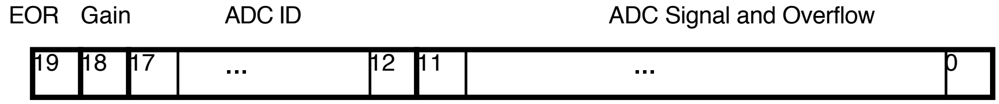


Figure 2.3: Event Record ADC Field. End of Record (EOR) and Gain bits are defined in Table 2.3.

The smallest event record (one event record header plus 2 ADC Fields) would be 72 bits long. A 3 ADC event would be 92 bits long. The event records will be padded by 4 bits for each event record with odd numbers of ADC Fields, allowing all event records to be aligned to byte boundaries. Table 2.4 and Figures 2.4–2.5 show some examples, with the Figures diagramming Event Records as 3 bytes wide for illustration only.

Table 2.4: Bit padding of Event Records.

# ADC Fields	# bits without padding	Padding bits	# bytes with padding
2	72	0	9
3	92	4	12
4	112	0	14
5	132	4	17
6	152	0	19
7	172	4	22

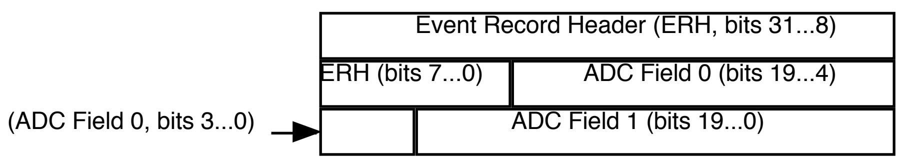


Figure 2.4: Event Record with 2 ADC Fields. Left to right is MSB to LSB, spanning 3 bytes.

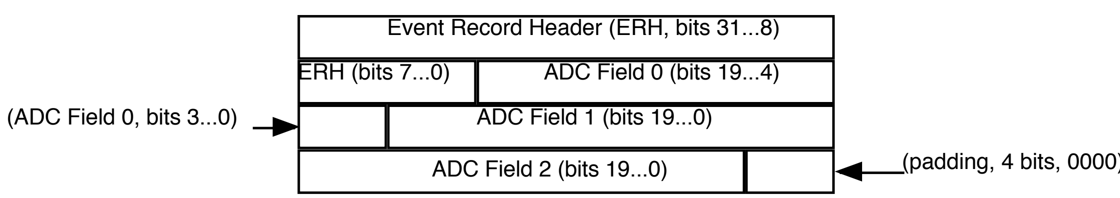


Figure 2.5: Event Record with 3 ADC Fields. Left to right is MSB to LSB, spanning 3 bytes.

Note: In the event of a bit error, particularly in the End of Record (EOR) bit in the ADC field, it is possible that all subsequent events in the Event Buffer will be unreconstructible or, at the very least, very difficult to reconstruct. Such bit errors are expected to be extremely rare. Possible remedies in the Event Record format may include enforcing MISC word boundaries for the ADC Field, and forcing bit 23 (EOR bit) in such ADC Fields to be 0 except at EOR. The disadvantage of this approach is an increase in the length in bytes of some events. The increasing number of unused bits in each event record will reduce the number of events possible in an Event Buffer.

Given the sizes of the Event Records and the included 4 bit padding of odd-number ADC events, Table 2.5 summarizes the Event Buffer capacity and the Telemetry Rate for events of up to 7 ADCs:

Table 2.5: Event Buffer Capacity and Telemetry Rate

# ADCs	Maximum # Events in Buffer	Telemetry Rate (events/sec)
2	303	5.1
3	227	3.8
4	195	3.3
5	160	2.7
6	143	2.4
7	124	2.1

Note that these estimates assume that the STIM Information Block (Section 2.10) and the Extended Header Block (Section 2.11) are not included in the event record.

2.10 Event Buffer – STIM Events

Bit 19 of the Event Record Header flags calibration, or STIM, events. These events include livetime STIM events and ADC STIM events. Both of these types of STIM events will be included in the Event Buffer, with different priorities and different (or unassigned) particle IDs. However, because they represent a different class of event than regular particles, it is anticipated that additional information may be needed for calibration and identification. Therefore, an additional 3-byte STIM Information Block is appended to the Event Record for STIM events, after the ADC fields and optional Extended Header block.

A two ADC STIM event is shown in Figure 2.6.

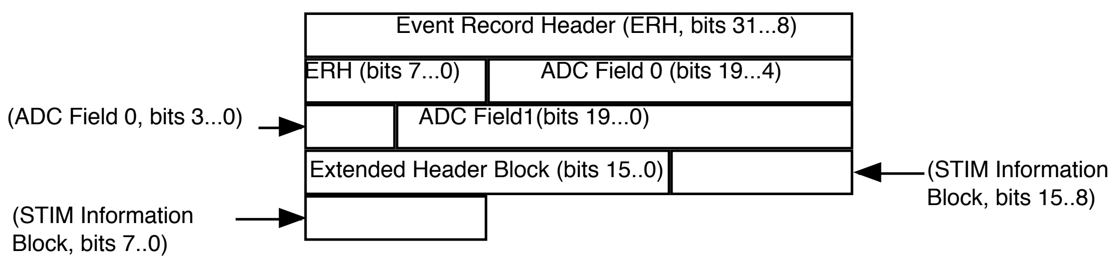


Figure 2.6: Event Record with 2 ADC Fields. Left to right is MSB to LSB, spanning 3 bytes. Optional Extended Header Block is also attached.

STIM events will be padded to fill out bytes in the same way that regular events are padded, at the end of the event record.

The STIM Information Block is appended after the Event Record Header if bit 30 of the ERH is set. The STIM information block contains a "seconds" counter, the DACLEVEL, and the DACCONFIGURATION. The seconds counter contains the second number within the accumulation minute of the LET Science Frame during which the STIM event was taken. For example, during normal mode operation, livetime STIM events are accumulated during the 0-8 second, 10-18 second, 20-28 second, etc. time intervals, while ADC STIM events are accumulated at the 9 second, 19 second, 29 second, etc. points. The DACLEVEL (0-31) and DACCONFIGURATION (0-14) indicate via tables in the LET onboard software what the DAC settings are for the STIM events and which ADCs are stimulated, respectively.

The bit assignments are defined elsewhere. The assumed arrangement of bits is shown in Figure 2.7.

SECONDS	DACLEVEL	DACCONFIGURATION
15 10	9 5	4 0

Figure 2.7: STIM Information Block

2.11 Extended Header Block

If bit 29 of the Event Record Header is set, an additional two byte Extended Header Block (or Extended Information Block) is appended after the ERH and ADC fields and before an optional STIM Information Block (Section 2.10). This Extended Header Block contains additional information useful for diagnosing onboard software function and performance.

The Extended Header Block currently contains DEINDEX (9 bits) and EPINDEX (7 bits). DEINDEX is the delta-E axis matrix index generated by the onboard software to map the given event to a LET Matrix Map (see Appendix C). It has a value in the range 0-399. EPINDEX is the residual energy axis matrix index (E-prime) generated by the onboard software to map the given event to a LET Matrix Map, and it has a value in the range 0-127.

DEINDEX	EPINDEX
15 7	6 0

Figure 2.8: Extended Header Block

3.0 LET Science Frame Format Summary

Tables 3.1–3.16 summarize the LET Science Data Frame Format, viewing the LET Data Frame as a stream of numbered bytes (0-4159). Descriptions of the contents of the Science Frame are given in Section 2, but these tables provide the byte locations of data elements in the LET Science Frame.

Note that the Science/Foreground Rates tables are quite long and span multiple pages.

Table 3.1: LET Science Data Frame Header Summary

Frame Byte # (First)	Frame Byte # (Last)	Description
0	0	Bits 6-7 = 00 (EM unit), 01 (FM1, ahead), 10 (FM2, behind) Bits 0-5 = frame version number
1	2	# Bytes used in Frame (SFLEN)
3	4	LET Science Frame Checksum (SFCHECK)

Table 3.2: Miscellaneous Bits, MISCBITS

Frame Byte # (First)	Frame Byte # (Last)	Description
5	5	Bit 7 = CodeOK Bits 3-6 = HeaterDutyCycle Bit 2 = LeakConv Bits 0-1 = DyThState
6	6	Minute (LET internal minute counter)

Table 3.3: Livetime Counters, ERATES (names **TBD**)

Frame Byte # (First)	Frame Byte # (Last)	Description
7	8	Livetime counter, Front End Electronics
9	10	# Triggers (NUMTRIG)
11	12	# Rejected Events (NUMREJECT)
13	14	# Accepted Events with PHA data (NUMACCPHA)
15	16	# Accepted Events without PHA data (NUMACCNPHA)
17	18	NUMTRIG.HAZ
19	20	NUMREJECT.HAZ
21	22	NUMACCPHA.HAZ
23	24	NUMACCNPHA.HAZ

Table 3.4: Singles Rates, SNGRATES

Frame Byte # (First)	Frame Byte # (Last)	# Bytes	Description	Detector Address
25	28	4	L2A0, High and Low Gain	0
29	32	4	L2A1, High and Low Gain	1
33	36	4	L2A2, High and Low Gain	2
37	40	4	L2A3, High and Low Gain	3
41	44	4	L2A4, High and Low Gain	4
45	48	4	L2A5, High and Low Gain	5
49	52	4	L2A6, High and Low Gain	6
53	56	4	L2A7, High and Low Gain	7
57	60	4	L2A8, High and Low Gain	8
61	64	4	L2A9, High and Low Gain	9
65	68	4	L3Ai, High and Low Gain	14
69	72	4	L3Ao, High and Low Gain	15
73	76	4	L1A0a, High and Low Gain	16
77	80	4	L1A0b, High and Low Gain	17
81	84	4	L1A0c, High and Low Gain	18
85	88	4	L1A1a, High and Low Gain	19
89	92	4	L1A1b, High and Low Gain	20
93	96	4	L1A1c, High and Low Gain	21
97	100	4	L1A2a, High and Low Gain	22
101	104	4	L1A2b, High and Low Gain	23
105	108	4	L1A2c, High and Low Gain	24
109	112	4	L1A3a, High and Low Gain	25
113	116	4	L1A3b, High and Low Gain	26
117	120	4	L1A3c, High and Low Gain	27
121	124	4	L1A4a, High and Low Gain	28
125	128	4	L1A4b, High and Low Gain	29
129	132	4	L1A4c, High and Low Gain	30
133	136	4	L1B0a, High and Low Gain	32
137	140	4	L1B0b, High and Low Gain	33
141	144	4	L1B0c, High and Low Gain	34
145	148	4	L1B1a, High and Low Gain	35
149	152	4	L1B1b, High and Low Gain	36
153	156	4	L1B1c, High and Low Gain	37
157	160	4	L1B2a, High and Low Gain	38

161	164	4	L1B2b, High and Low Gain	39
165	168	4	L1B2c, High and Low Gain	40
169	172	4	L1B3a, High and Low Gain	41
173	176	4	L1B3b, High and Low Gain	42
177	180	4	L1B3c, High and Low Gain	43
181	184	4	L1B4a, High and Low Gain	44
185	188	4	L1B4b, High and Low Gain	45
189	192	4	L1B4c, High and Low Gain	46
193	196	4	L2B0, High and Low Gain	48
197	200	4	L2B1, High and Low Gain	49
201	204	4	L2B2, High and Low Gain	50
205	208	4	L2B3, High and Low Gain	51
209	212	4	L2B4, High and Low Gain	52
213	216	4	L2B5, High and Low Gain	53
217	220	4	L2B6, High and Low Gain	54
221	224	4	L2B7, High and Low Gain	55
225	228	4	L2B8, High and Low Gain	56
229	232	4	L2B9, High and Low Gain	57
233	236	4	L3Bi, High and Low Gain	62
237	240	4	L3Bo, High and Low Gain	63

Table 3.5: Miscellaneous Rates, MISCRATES (**TBD**)

Frame Byte # (First)	Frame Byte # (Last)	# Bytes	Description
241	250	10	Miscellaneous instrument rates (**TBD**)

Table 3.6: Event Processing Rates, EVPRATES

Frame Byte # (First)	Frame Byte # (Last)	Description
251	252	NREAD (events read from event FIFO)
253	254	NHAZ (events rejected for Hazard condition)
255	256	NADCSTIM (ADC-calibration STIM events)
257	258	NODD (odd events)
259	260	NODDFIX (fixed odd events)
261	262	NMULTI (events with multiple hits in relevant layers)
263	264	NMULTIFIX (fixed multi events)
265	266	NBADTRAJ (events rejected for inconsistent/bad trajectory)
267	268	NL2 (events sorted into L12 event category)
269	270	NL3 (events sorted into L123 event category)
271	272	NPEN (events sorted into PEN event category)
273	274	NFORMAT (events handled by the telemetry event formatter)
275	276	NASIDE (events the software assumed were Aside events)
277	278	NBSIDE (events the software assumed were Bside events)
279	280	NERROR (events that caused a processing error - should never happen)
281	282	NBADTAGS (events with bad tags from onboard event-processing)

Table 3.7: Coincidence Rates, COINRATES

Frame Byte # (First)	Frame Byte # (Last)	# Bytes	Description
283	284	2	L12A
285	286	2	L123A
287	288	2	PENA
289	290	2	spare
291	292	2	L12B
293	294	2	L123B
295	296	2	PENB
297	298	2	spare
299	300	2	PENA?
301	302	2	PENB?
303	304	2	2TEL
305	306	2	ERRTAG

Table 3.8: Priority Buffer Rates, BUFRATES

Frame Byte # (First)	Frame Byte # (Last)	Description
307	308	PB #0 ADC-cal events
309	310	PB #1 Range 2, 3, or 4 events that fall into Z>=40 matrix box
311	312	PB #2 Range 2, 3, or 4 events that fall into 31<=Z<=39 matrix box
313	314	PB #3 Range 3 events that fall into 9<=Z<=30 matrix box, or any foreground box that is painted over it.
315	316	PB #4 Range 2 events that fall into 9<=Z<=30 matrix box, or any foreground box that is painted over it.
317	318	PB #5 Range 3 events that fall into the LiBeB, CNO, C, N, or O matrix boxes
319	320	PB #6 Range 2 events that fall into the LiBeB, CNO, C, N, or O matrix boxes
321	322	PB #7 Range 4 events that fall into the LiBeB, CNO, or 9<=Z<=30 matrix boxes, or any foreground matrix box from C thru Ni.
323	324	PB #8 Range 4 events that fall into the PEN_Z>30 matrix box ("penetrating" or "Range 5" events)
325	326	PB #9 Matrix-sort Reject events, with L3 signal, Z>=3
327	328	PB #10 Matrix-sort Reject events, with NO L3 signal, Z>=3
329	330	PB #11 Range 3 events that fall into 3He matrix box
331	332	PB #12 Range 2 events that fall into 3He matrix box
333	334	PB #13 Range 4 events that fall into the PEN_3<=Z<=30 matrix box ("penetrating" or "Range 5" events)
335	336	PB #14 Range 3 events that fall into the He background or 4He foreground matrix box
337	338	PB #15 Range 4 events that fall into any He matrix box
339	340	PB #16 Range 2 events that fall into the He background or 4He foreground matrix box
341	342	PB #17 Range 3 events that fall into any H matrix box
343	344	PB #18 Range 4 events that fall into any H matrix box
345	346	PB #19 Range 2 events that fall into any H matrix box
347	348	PB #20 Matrix-sort Reject events, with L3 signal, Z<3

349	350	PB #21 Matrix-sort Reject events, with NO L3 signal, Z<3
351	352	PB #22 Range 4 events that fall into the PEN_H_He matrix box ("penetrating" or "Range 5" events)
353	354	PB #23 Range 2, 3, or 4 events that fall into the "Backward" matrix box
355	356	PB #24 "Clean" Livetime STIM events (stim events that fall into a STIM matrix box)
357	358	PB #25 "Poor" Livetime STIM events (stim events that either fall outside a STIM matrix box, or are rejected because of multiple hits in a layer, etc.)
359	360	PB #26 ERROR - Onboard processing of the event was aborted due to an error. Occurs if the tag-bits of the event are invalid. Can also occur if the onboard processing reaches a point that it should never reach.
361	362	PB #27 Other - currently not used
363	364	PB #28 Spare

Table 3.9: LET Science Data Frame, Range 2 (L1L2) Science/Foreground Rates, L2FGRATES

Frame Byte # (First)	Frame Byte # (Last)	Description	Particle ID
365	366	H (1.0-1.8 MeV/nuc)	0
367	368	H (1.8-2.2 MeV/nuc)	1
369	370	H (2.2-2.7 MeV/nuc)	2
371	372	H (2.7-3.2 MeV/nuc)	3
373	374	H (3.2-3.6 MeV/nuc)	4
375	376	H (3.6-4.0 MeV/nuc)	5
377	378	H (4.0-4.5 MeV/nuc)	6
379	380	H (4.5-5.0 MeV/nuc)	7
381	382	H (5.0-70.0 MeV/nuc)	8
383	384	He-3 (1.0-2.2 MeV/nuc)	9
385	386	He-3 (2.2-2.7 MeV/nuc)	10
387	388	He-3 (2.7-3.2 MeV/nuc)	11
389	390	He-3 (3.2-3.6 MeV/nuc)	12
391	392	He-3 (3.6-4.0 MeV/nuc)	13
393	394	He-3 (4.0-4.5 MeV/nuc)	14
395	396	He-3 (4.5-5.0 MeV/nuc)	15
397	398	He-3 (5.0-6.0 MeV/nuc)	16
399	400	He-3 (6.0-70.0 MeV/nuc)	17
401	402	He-4 (1.0-1.8 MeV/nuc)	18
403	404	He-4 (1.8-2.2 MeV/nuc)	19
405	406	He-4 (2.2-2.7 MeV/nuc)	20
407	408	He-4 (2.7-3.2 MeV/nuc)	21
409	410	He-4 (3.2-3.6 MeV/nuc)	22
411	412	He-4 (3.6-4.0 MeV/nuc)	23
413	414	He-4 (4.0-4.5 MeV/nuc)	24
415	416	He-4 (4.5-5.0 MeV/nuc)	25
417	418	He-4 (5.0-70.0 MeV/nuc)	26
419	420	C (1.0-3.2 MeV/nuc)	27
421	422	C (3.2-3.6 MeV/nuc)	28
423	424	C (3.6-4.0 MeV/nuc)	29
425	426	C (4.0-4.5 MeV/nuc)	30
427	428	C (4.5-5.0 MeV/nuc)	31

429	430	C (5.0-6.0 MeV/nuc)	32
431	432	C (6.0-8.0 MeV/nuc)	33
433	434	C (8.0-10.0 MeV/nuc)	34
435	436	C (10.0-70.0 MeV/nuc)	35
437	438	N (1.0-3.2 MeV/nuc)	36
439	440	N (3.2-3.6 MeV/nuc)	37
441	442	N (3.6-4.0 MeV/nuc)	38
443	444	N (4.0-4.5 MeV/nuc)	39
445	446	N (4.5-5.0 MeV/nuc)	40
447	448	N (5.0-6.0 MeV/nuc)	41
449	450	N (6.0-8.0 MeV/nuc)	42
451	452	N (8.0-10.0 MeV/nuc)	43
453	454	N (10.0-70.0 MeV/nuc)	44
455	456	O (1.0-3.2 MeV/nuc)	45
457	458	O (3.2-3.6 MeV/nuc)	46
459	460	O (3.6-4.0 MeV/nuc)	47
461	462	O (4.0-4.5 MeV/nuc)	48
463	464	O (4.5-5.0 MeV/nuc)	49
465	466	O (5.0-6.0 MeV/nuc)	50
467	468	O (6.0-8.0 MeV/nuc)	51
469	470	O (8.0-10.0 MeV/nuc)	52
471	472	O (10.0-70.0 MeV/nuc)	53
473	474	Ne (1.0-3.2 MeV/nuc)	54
475	476	Ne (3.2-3.6 MeV/nuc)	55
477	478	Ne (3.6-4.0 MeV/nuc)	56
479	480	Ne (4.0-4.5 MeV/nuc)	57
481	482	Ne (4.5-5.0 MeV/nuc)	58
483	484	Ne (5.0-6.0 MeV/nuc)	59
485	486	Ne (6.0-8.0 MeV/nuc)	60
487	488	Ne (8.0-10.0 MeV/nuc)	61
489	490	Ne (10.0-12.0 MeV/nuc)	62
491	492	Ne (12.0-70.0 MeV/nuc)	63
493	494	Mg (1.0-3.2 MeV/nuc)	64
495	496	Mg (3.2-3.6 MeV/nuc)	65
497	498	Mg (3.6-4.0 MeV/nuc)	66
499	500	Mg (4.0-4.5 MeV/nuc)	67
501	502	Mg (4.5-5.0 MeV/nuc)	68
503	504	Mg (5.0-6.0 MeV/nuc)	69
505	506	Mg (6.0-8.0 MeV/nuc)	70
507	508	Mg (8.0-10.0 MeV/nuc)	71
509	510	Mg (10.0-12.0 MeV/nuc)	72
511	512	Mg (12.0-15.0 MeV/nuc)	73
513	514	Mg (15.0-70.0 MeV/nuc)	74
515	516	Si (1.0-3.2 MeV/nuc)	75
517	518	Si (3.2-3.6 MeV/nuc)	76
519	520	Si (3.6-4.0 MeV/nuc)	77
521	522	Si (4.0-4.5 MeV/nuc)	78
523	524	Si (4.5-5.0 MeV/nuc)	79
525	526	Si (5.0-6.0 MeV/nuc)	80
527	528	Si (6.0-8.0 MeV/nuc)	81
529	530	Si (8.0-10.0 MeV/nuc)	82
531	532	Si (10.0-12.0 MeV/nuc)	83

533	534	Si (12.0-15.0 MeV/nuc)	84
535	536	Si (15.0-70.0 MeV/nuc)	85
537	538	S (1.0-3.6 MeV/nuc)	86
539	540	S (3.6-4.0 MeV/nuc)	87
541	542	S (4.0-4.5 MeV/nuc)	88
543	544	S (4.5-5.0 MeV/nuc)	89
545	546	S (5.0-6.0 MeV/nuc)	90
547	548	S (6.0-8.0 MeV/nuc)	91
549	550	S (8.0-10.0 MeV/nuc)	92
551	552	S (10.0-12.0 MeV/nuc)	93
553	554	S (12.0-15.0 MeV/nuc)	94
555	556	S (15.0-70.0 MeV/nuc)	95
557	558	Ar (1.0-3.6 MeV/nuc)	96
559	560	Ar (3.6-4.0 MeV/nuc)	97
561	562	Ar (4.0-4.5 MeV/nuc)	98
563	564	Ar (4.5-5.0 MeV/nuc)	99
565	566	Ar (5.0-6.0 MeV/nuc)	100
567	568	Ar (6.0-8.0 MeV/nuc)	101
569	570	Ar (8.0-10.0 MeV/nuc)	102
571	572	Ar (10.0-12.0 MeV/nuc)	103
573	574	Ar (12.0-15.0 MeV/nuc)	104
575	576	Ar (15.0-21.0 MeV/nuc)	105
577	578	Ar (21.0-70.0 MeV/nuc)	106
579	580	Ca (1.0-3.6 MeV/nuc)	107
581	582	Ca (3.6-4.0 MeV/nuc)	108
583	584	Ca (4.0-4.5 MeV/nuc)	109
585	586	Ca (4.5-5.0 MeV/nuc)	110
587	588	Ca (5.0-6.0 MeV/nuc)	111
589	590	Ca (6.0-8.0 MeV/nuc)	112
591	592	Ca (8.0-10.0 MeV/nuc)	113
593	594	Ca (10.0-12.0 MeV/nuc)	114
595	596	Ca (12.0-15.0 MeV/nuc)	115
597	598	Ca (15.0-21.0 MeV/nuc)	116
599	600	Ca (21.0-70.0 MeV/nuc)	117
601	602	Fe (1.0-2.7 MeV/nuc)	118
603	604	Fe (2.7-3.2 MeV/nuc)	119
605	606	Fe (3.2-3.6 MeV/nuc)	120
607	608	Fe (3.6-4.0 MeV/nuc)	121
609	610	Fe (4.0-4.5 MeV/nuc)	122
611	612	Fe (4.5-5.0 MeV/nuc)	123
613	614	Fe (5.0-6.0 MeV/nuc)	124
615	616	Fe (6.0-8.0 MeV/nuc)	125
617	618	Fe (8.0-10.0 MeV/nuc)	126
619	620	Fe (10.0-12.0 MeV/nuc)	127
621	622	Fe (12.0-15.0 MeV/nuc)	128
623	624	Fe (15.0-21.0 MeV/nuc)	129
625	626	Fe (21.0-70.0 MeV/nuc)	130
627	628	Na, Al, Ni, unidentified	255

Table 3.10: LET Science Data Frame, Range 2 (L1L2) Science/Background Rates, L2BGRATES

Frame Byte # (First)	Frame Byte # (Last)	Description	Particle ID
629	630	H Background	255
631	632	He Background	255
633	634	LiBeB Background	255
635	636	CNO Background	255
637	638	Z=9-30 Background	255
639	640	Z=30-40 Background	255
641	642	Z>=40 Background	255
643	644	Backward Background	255
645	646	H, He STIM	255
647	648	CNO STIM	255
649	650	Fe STIM	255
651	652	STIM error	255

Table 3.11: LET Science Data Frame, Range 3 (L2L3) Science/Foreground Rates, L3FGRATES

Frame Byte # (First)	Frame Byte # (Last)	Description	Particle ID
653	654	H (1.0-3.2 MeV/nuc)	0
655	656	H (3.2-3.6 MeV/nuc)	1
657	658	H (3.6-4.0 MeV/nuc)	2
659	660	H (4.0-4.5 MeV/nuc)	3
661	662	H (4.5-5.0 MeV/nuc)	4
663	664	H (5.0-6.0 MeV/nuc)	5
665	666	H (6.0-8.0 MeV/nuc)	6
667	668	H (8.0-10.0 MeV/nuc)	7
669	670	H (10.0-12.0 MeV/nuc)	8
671	672	H (12.0-15.0 MeV/nuc)	9
673	674	H (15.0-70.0 MeV/nuc)	10
675	676	He-3 (1.0-4.0 MeV/nuc)	11
677	678	He-3 (4.0-4.5 MeV/nuc)	12
679	680	He-3 (4.5-5.0 MeV/nuc)	13
681	682	He-3 (5.0-6.0 MeV/nuc)	14
683	684	He-3 (6.0-8.0 MeV/nuc)	15
685	686	He-3 (8.0-10.0 MeV/nuc)	16
687	688	He-3 (10.0-12.0 MeV/nuc)	17
689	690	He-3 (12.0-15.0 MeV/nuc)	18
691	692	He-3 (15.0-70.0 MeV/nuc)	19
693	694	He-4 (1.0-3.2 MeV/nuc)	20
695	696	He-4 (3.2-3.6 MeV/nuc)	21
697	698	He-4 (3.6-4.0 MeV/nuc)	22
699	700	He-4 (4.0-4.5 MeV/nuc)	23
701	702	He-4 (4.5-5.0 MeV/nuc)	24
703	704	He-4 (5.0-6.0 MeV/nuc)	25
705	706	He-4 (6.0-8.0 MeV/nuc)	26
707	708	He-4 (8.0-10.0 MeV/nuc)	27
709	710	He-4 (10.0-12.0 MeV/nuc)	28
711	712	He-4 (12.0-15.0 MeV/nuc)	29
713	714	He-4 (15.0-70.0 MeV/nuc)	30

715	716	C (1.0-4.5 MeV/nuc)	31
717	718	C (4.5-5.0 MeV/nuc)	32
719	720	C (5.0-6.0 MeV/nuc)	33
721	722	C (6.0-8.0 MeV/nuc)	34
723	724	C (8.0-10.0 MeV/nuc)	35
725	726	C (10.0-12.0 MeV/nuc)	36
727	728	C (12.0-15.0 MeV/nuc)	37
729	730	C (15.0-21.0 MeV/nuc)	38
731	732	C (21.0-27.0 MeV/nuc)	39
733	734	C (27.0-33.0 MeV/nuc)	40
735	736	C (33.0-70.0 MeV/nuc)	41
737	738	N (1.0-5.0 MeV/nuc)	42
739	740	N (5.0-6.0 MeV/nuc)	43
741	742	N (6.0-8.0 MeV/nuc)	44
743	744	N (8.0-10.0 MeV/nuc)	45
745	746	N (10.0-12.0 MeV/nuc)	46
747	748	N (12.0-15.0 MeV/nuc)	47
749	750	N (15.0-21.0 MeV/nuc)	48
751	752	N (21.0-27.0 MeV/nuc)	49
753	754	N (27.0-33.0 MeV/nuc)	50
755	756	N (33.0-70.0 MeV/nuc)	51
757	758	O (1.0-5.0 MeV/nuc)	52
759	760	O (5.0-6.0 MeV/nuc)	53
761	762	O (6.0-8.0 MeV/nuc)	54
763	764	O (8.0-10.0 MeV/nuc)	55
765	766	O (10.0-12.0 MeV/nuc)	56
767	768	O (12.0-15.0 MeV/nuc)	57
769	770	O (15.0-21.0 MeV/nuc)	58
771	772	O (21.0-27.0 MeV/nuc)	59
773	774	O (27.0-33.0 MeV/nuc)	60
775	776	O (33.0-70.0 MeV/nuc)	61
777	778	Ne (1.0-6.0 MeV/nuc)	62
779	780	Ne (6.0-8.0 MeV/nuc)	63
781	782	Ne (8.0-10.0 MeV/nuc)	64
783	784	Ne (10.0-12.0 MeV/nuc)	65
785	786	Ne (12.0-15.0 MeV/nuc)	66
787	788	Ne (15.0-21.0 MeV/nuc)	67
789	790	Ne (21.0-27.0 MeV/nuc)	68
791	792	Ne (27.0-33.0 MeV/nuc)	69
793	794	Ne (33.0-40.0 MeV/nuc)	70
795	796	Ne (40.0-70.0 MeV/nuc)	71
797	798	Na (1.0-6.0 MeV/nuc)	72
799	800	Na (6.0-8.0 MeV/nuc)	73
801	802	Na (8.0-10.0 MeV/nuc)	74
803	804	Na (10.0-12.0 MeV/nuc)	75
805	806	Na (12.0-15.0 MeV/nuc)	76
807	808	Na (15.0-21.0 MeV/nuc)	77
809	810	Na (21.0-27.0 MeV/nuc)	78
811	812	Na (27.0-33.0 MeV/nuc)	79
813	814	Na (33.0-40.0 MeV/nuc)	80
815	816	Na (40.0-70.0 MeV/nuc)	81
817	818	Mg (1.0-6.0 MeV/nuc)	82

819	820	Mg (6.0-8.0 MeV/nuc)	83
821	822	Mg (8.0-10.0 MeV/nuc)	84
823	824	Mg (10.0-12.0 MeV/nuc)	85
825	826	Mg (12.0-15.0 MeV/nuc)	86
827	828	Mg (15.0-21.0 MeV/nuc)	87
829	830	Mg (21.0-27.0 MeV/nuc)	88
831	832	Mg (27.0-33.0 MeV/nuc)	89
833	834	Mg (33.0-40.0 MeV/nuc)	90
835	836	Mg (40.0-52.0 MeV/nuc)	91
837	838	Mg (52.0-70.0 MeV/nuc)	92
839	840	Al (1.0-6.0 MeV/nuc)	93
841	842	Al (6.0-8.0 MeV/nuc)	94
843	844	Al (8.0-10.0 MeV/nuc)	95
845	846	Al (10.0-12.0 MeV/nuc)	96
847	848	Al (12.0-15.0 MeV/nuc)	97
849	850	Al (15.0-21.0 MeV/nuc)	98
851	852	Al (21.0-27.0 MeV/nuc)	99
853	854	Al (27.0-33.0 MeV/nuc)	100
855	856	Al (33.0-40.0 MeV/nuc)	101
857	858	Al (40.0-52.0 MeV/nuc)	102
859	860	Al (52.0-70.0 MeV/nuc)	103
861	862	Si (1.0-6.0 MeV/nuc)	104
863	864	Si (6.0-8.0 MeV/nuc)	105
865	866	Si (8.0-10.0 MeV/nuc)	106
867	868	Si (10.0-12.0 MeV/nuc)	107
869	870	Si (12.0-15.0 MeV/nuc)	108
871	872	Si (15.0-21.0 MeV/nuc)	109
873	874	Si (21.0-27.0 MeV/nuc)	110
875	876	Si (27.0-33.0 MeV/nuc)	111
877	878	Si (33.0-40.0 MeV/nuc)	112
879	880	Si (40.0-52.0 MeV/nuc)	113
881	882	Si (52.0-70.0 MeV/nuc)	114
883	884	S (1.0-6.0 MeV/nuc)	115
885	886	S (6.0-8.0 MeV/nuc)	116
887	888	S (8.0-10.0 MeV/nuc)	117
889	890	S (10.0-12.0 MeV/nuc)	118
891	892	S (12.0-15.0 MeV/nuc)	119
893	894	S (15.0-21.0 MeV/nuc)	120
895	896	S (21.0-27.0 MeV/nuc)	121
897	898	S (27.0-33.0 MeV/nuc)	122
899	900	S (33.0-40.0 MeV/nuc)	123
901	902	S (40.0-52.0 MeV/nuc)	124
903	904	S (52.0-70.0 MeV/nuc)	125
905	906	Ar (1.0-6.0 MeV/nuc)	126
907	908	Ar (6.0-8.0 MeV/nuc)	127
909	910	Ar (8.0-10.0 MeV/nuc)	128
911	912	Ar (10.0-12.0 MeV/nuc)	129
913	914	Ar (12.0-15.0 MeV/nuc)	130
915	916	Ar (15.0-21.0 MeV/nuc)	131
917	918	Ar (21.0-27.0 MeV/nuc)	132
919	920	Ar (27.0-33.0 MeV/nuc)	133
921	922	Ar (33.0-40.0 MeV/nuc)	134

923	924	Ar (40.0-52.0 MeV/nuc)	135
925	926	Ar (52.0-70.0 MeV/nuc)	136
927	928	Ca (1.0-8.0 MeV/nuc)	137
929	930	Ca (8.0-10.0 MeV/nuc)	138
931	932	Ca (10.0-12.0 MeV/nuc)	139
933	934	Ca (12.0-15.0 MeV/nuc)	140
935	936	Ca (15.0-21.0 MeV/nuc)	141
937	938	Ca (21.0-27.0 MeV/nuc)	142
939	940	Ca (27.0-33.0 MeV/nuc)	143
941	942	Ca (33.0-40.0 MeV/nuc)	144
943	944	Ca (40.0-52.0 MeV/nuc)	145
945	946	Ca (52.0-70.0 MeV/nuc)	146
947	948	Fe (1.0-8.0 MeV/nuc)	147
949	950	Fe (8.0-10.0 MeV/nuc)	148
951	952	Fe (10.0-12.0 MeV/nuc)	149
953	954	Fe (12.0-15.0 MeV/nuc)	150
955	956	Fe (15.0-21.0 MeV/nuc)	151
957	958	Fe (21.0-27.0 MeV/nuc)	152
959	960	Fe (27.0-33.0 MeV/nuc)	153
961	962	Fe (33.0-40.0 MeV/nuc)	154
963	964	Fe (40.0-52.0 MeV/nuc)	155
965	966	Fe (52.0-70.0 MeV/nuc)	156
967	968	Ni (1.0-8.0 MeV/nuc)	157
969	970	Ni (8.0-10.0 MeV/nuc)	158
971	972	Ni (10.0-12.0 MeV/nuc)	159
973	974	Ni (12.0-15.0 MeV/nuc)	160
975	976	Ni (15.0-21.0 MeV/nuc)	161
977	978	Ni (21.0-27.0 MeV/nuc)	162
979	980	Ni (27.0-33.0 MeV/nuc)	163
981	982	Ni (33.0-40.0 MeV/nuc)	164
983	984	Ni (40.0-52.0 MeV/nuc)	165
985	986	Ni (52.0-70.0 MeV/nuc)	166

Table 3.12: LET Science Data Frame, Range 3 (L2L3) Science/Background Rates, L3BGRATES

Frame Byte # (First)	Frame Byte # (Last)	Description	Particle ID
987	988	H Background	255
989	990	He Background	255
991	992	LiBeB Background	255
993	994	CNO Background	255
995	996	Z=9-30 Background	255
997	998	Z=30-40 Background	255
999	1000	Z>=40 Background	255
1001	1002	Backward Background	255
1003	1004	H, He STIM	255
1005	1006	CNO STIM	255
1007	1008	Fe STIM	255
1009	1010	STIM error	255

Table 3.13: LET Science Data Frame, Range 4 (L3AL3B) Science/Foreground Rates, PENFGRATES

Frame Byte # (First)	Frame Byte # (Last)	Description	Particle ID
1011	1012	H (1.0-12.0 MeV/nuc)	0
1013	1014	H (12.0-15.0 MeV/nuc)	1
1015	1016	H (15.0-70.0 MeV/nuc)	2
1017	1018	He-4 (1.0-12.0 MeV/nuc)	3
1019	1020	He-4 (12.0-15.0 MeV/nuc)	4
1021	1022	He-4 (15.0-70.0 MeV/nuc)	5
1023	1024	C (1.0-21.0 MeV/nuc)	6
1025	1026	C (21.0-27.0 MeV/nuc)	7
1027	1028	C (27.0-33.0 MeV/nuc)	8
1029	1030	C (33.0-70.0 MeV/nuc)	9
1031	1032	N (1.0-21.0 MeV/nuc)	10
1033	1034	N (21.0-27.0 MeV/nuc)	11
1035	1036	N (27.0-33.0 MeV/nuc)	12
1037	1038	N (33.0-70.0 MeV/nuc)	13
1039	1040	O (1.0-27.0 MeV/nuc)	14
1041	1042	O (27.0-33.0 MeV/nuc)	15
1043	1044	O (33.0-70.0 MeV/nuc)	16
1045	1046	Ne (1.0-27.0 MeV/nuc)	17
1047	1048	Ne (27.0-33.0 MeV/nuc)	18
1049	1050	Ne (33.0-40.0 MeV/nuc)	19
1051	1052	Ne (40.0-70.0 MeV/nuc)	20
1053	1054	Mg (1.0-33.0 MeV/nuc)	21
1055	1056	Mg (33.0-40.0 MeV/nuc)	22
1057	1058	Mg (40.0-52.0 MeV/nuc)	23
1059	1060	Mg (52.0-70.0 MeV/nuc)	24
1061	1062	Si (1.0-33.0 MeV/nuc)	25
1063	1064	Si (33.0-40.0 MeV/nuc)	26
1065	1066	Si (40.0-52.0 MeV/nuc)	27
1067	1068	Si (52.0-70.0 MeV/nuc)	28
1069	1070	Fe (1.0-40.0 MeV/nuc)	29
1071	1072	Fe (40.0-52.0 MeV/nuc)	30
1073	1074	Fe (52.0-70.0 MeV/nuc)	31
1075	1076	He-3, Na, Al, S, Ar, Ca, Ni, Unidentified	255

Table 3.14: LET Science Data Frame, Range 4 (L3AL3B) Science/Background Rates, PENBGRATES

Frame Byte # (First)	Frame Byte # (Last)	Description	Particle ID
1077	1078	H Background	255
1079	1080	He Background	255
1081	1082	LiBeB Background	255
1083	1084	CNO Background	255
1085	1086	Z=9-30 Background	255
1087	1088	Z=30-40 Background	255
1089	1090	Z>=40 Background	255
1091	1092	Backward Background	255
1093	1094	H, He PEN	255
1095	1096	Z=3-30 PEN	255

1097	1098	Z>30 PEN	255
1099	1100	H, He STIM	255
1101	1102	CNO STIM	255
1103	1104	Fe STIM	255
1105	1106	STIM error	255

Table 3.15: LET Science Data Frame, Look Direction/Sectored Rates, SECTRATES

Frame Byte # (First)	Frame Byte # (Last)	# Bytes	Description
1107	1122	16	H, 4-6 MeV, Side A (Look Directions 0-7)
1123	1138	16	H, 4-6 MeV, Side B (Look Directions 8-15)
1139	1154	16	He-3, 4-6 MeV/nuc, Side A (Look Directions 0-7)
1155	1170	16	He-3, 4-6 MeV/nuc, Side B (Look Directions 8-15)
1171	1186	16	He-4, 4-6 MeV/nuc, Side A (Look Directions 0-7)
1187	1202	16	He-4, 4-6 MeV/nuc, Side B (Look Directions 8-15)
1203	1218	16	He-4, 6-12 MeV/nuc, Side A (Look Directions 0-7)
1219	1234	16	He-4, 6-12 MeV/nuc, Side B (Look Directions 8-15)
1235	1250	16	CNO, 4-6 MeV/nuc, Side A (Look Directions 0-7)
1251	1266	16	CNO, 4-6 MeV/nuc, Side B (Look Directions 8-15)
1267	1282	16	CNO, 6-12 MeV/nuc, Side A (Look Directions 0-7)
1283	1298	16	CNO, 6-12 MeV/nuc, Side B (Look Directions 8-15)
1299	1314	16	NeMgSi, 4-6 MeV/nuc, Side A (Look Directions 0-7)
1315	1330	16	NeMgSi, 4-6 MeV/nuc, Side B (Look Directions 8-15)
1331	1346	16	NeMgSi, 6-12 MeV/nuc, Side A (Look Directions 0-7)
1347	1362	16	NeMgSi, 6-12 MeV/nuc, Side B (Look Directions 8-15)
1363	1378	16	Fe, 4-6 MeV/nuc, Side A (Look Directions 0-7)
1379	1394	16	Fe, 4-6 MeV/nuc, Side B (Look Directions 8-15)
1395	1410	16	Fe, 6-12 MeV/nuc, Side A (Look Directions 0-7)
1411	1426	16	Fe, 6-12 MeV/nuc, Side B (Look Directions 8-15)

Table 3.16: LET Science Data Frame, Event Buffer

Frame Byte # (First)	Frame Byte # (Last)	Description
1427	1428	Event Buffer Header (# Event Records)
1429	4159	Event Records (filled as needed)

Appendix A: Rates Compression/Decompression Algorithm

The following algorithms were suggested in an e-mail from Don Reames, for compressing 32 bits to 16 bits. This finalized algorithm is a modified biased exponent, hidden one algorithm with a 12 bit mantissa and a 4 bit exponent. Numbers up to 2^{12} are uncompressed, and numbers up to 2^{13} decompress with no "error".

```
/* Rewrite to allow flexible arrangements of bits. AWL 030909 */
unsigned int num_bits=16, num_mantissa_bits=12, num_exponent_bits=4;
unsigned long output_mask=0xffff; /* 0xffff 16 bit, 0x0fff 12 bit */

/* 32-bit -> 16-bit compression for SW and HW rates      */
/* useage:  rateout=pack_rate(ratein);                    */

unsigned int pack_rate(ratein)
long ratein;
{
	unsigned int rateout, power=0;
	unsigned long mask;

	mask = (0xffffffff<<(num_mantissa_bits+1));
	while (ratein&mask)
	{
		power += (0x0001<<num_mantissa_bits);
		ratein>>=1;
	}
	rateout=ratein;
	if (power)
	{
		rateout = power + (0x0001<<num_mantissa_bits)
			| (rateout & (output_mask>>num_exponent_bits));
	}

	rateout = (rateout & output_mask);

	return rateout;
}

/* Unpacking (not required in flight code) */
/* switched from long to unsigned long -- AWL 011107 */
unsigned long long_rate(packed) /* Unpack to long */
unsigned long packed;           /* was just long.  AWL 030908 */
{
	unsigned long power;        /* was just long.  AWL 030908 */
	unsigned long out;  /* was just long.  AWL 030908 */

	power = packed>>num_mantissa_bits;
	if (power>1)
	{
		out = ( (packed & (output_mask>>num_exponent_bits))
			| (0x0001<<num_mantissa_bits) );
		out = out<<(power-1);
```

```
        }
        else
                out = packed;
        return out;
}

double dbl_rate(packed) /* Unpack to double */
unsigned packed;
{
        int power;
        double out;

        power = packed>>num_mantissa_bits;
        if (power>1)
        {
                out = ( (packed & (output_mask>>num_exponent_bits))
                        | (0x0001<<num_mantissa_bits) );
                out = out * pow(2.,(double)(power-1));
        }
        else
                out = packed;
        return out;
}
```

Appendix B: Outstanding Issues

- Verify checksum algorithm.
- Define event sampling algorithm here or point to definition in some other document (e.g. is it already in *STEREO-CIT-002.F STEREO SEP LET and SEP Central Flight Software Requirements*?).
- Need formal documentation for livetimes, Event Processing Counters, and Priority Buffer Counters, and their uses. Priority Buffers are set out in RAM memos, and Event Processing Counters are listed in *LET Software Counter Definitions* (*STEREO-CIT-019.A*). Documentation should be entered in the STEREO/LET Documentation catalog. (Section 2.7.)
- Misc. Rates need to be defined. (Section 2.8).
- Define hazard condition for HAZ flag in Event Record Header.
- Set maximum number of ADCs to be included in Event Records, and define the ADC selection criteria when the number of hit ADCs passes the maximum. Didn't we already do this?
- Verify STIM information block format for STIM Event Record Headers.
- Verify Extended Header format..

Appendix C: LET Matrices

The LET Matrices are used in onboard processing for identifying particles by penetration range, element, and energy, using the delta–E vs. E' technique. The matrices and their use in the onboard software are documented elsewhere. However, for purposes of illustration, graphical representations of the matrices are included in this Appendix.

The matrices are 128 bins (x–axis) by 400 bins (y–axis), mapped over delta–E vs E' space. Each bin contains a number identifying either a "foreground" particle (selected elements or helium isotopes) or a "background" particle. Colors in the figures are assigned according to the bin value, but the colors are not unique to the bin values. Rather, light orange, red, and green were selected to contrast adjacent foreground tracks, and shades of blue and purple were selected to contrast adjacent background regions. The white (uncolored) region bounds backward–going particles, and STIM boxes are bright orange.

Solid yellow and dashed green lines center and outline the particle tracks for selected elements and helium isotopes. The curves were calculated using the Andersen and Ziegler (1977) range–energy relationship, assuming normal incidence through the LET detectors. The points are simulation data (M. Wiedenbeck, run 050).

The Matrices represented by the following plots are at Version 8e.

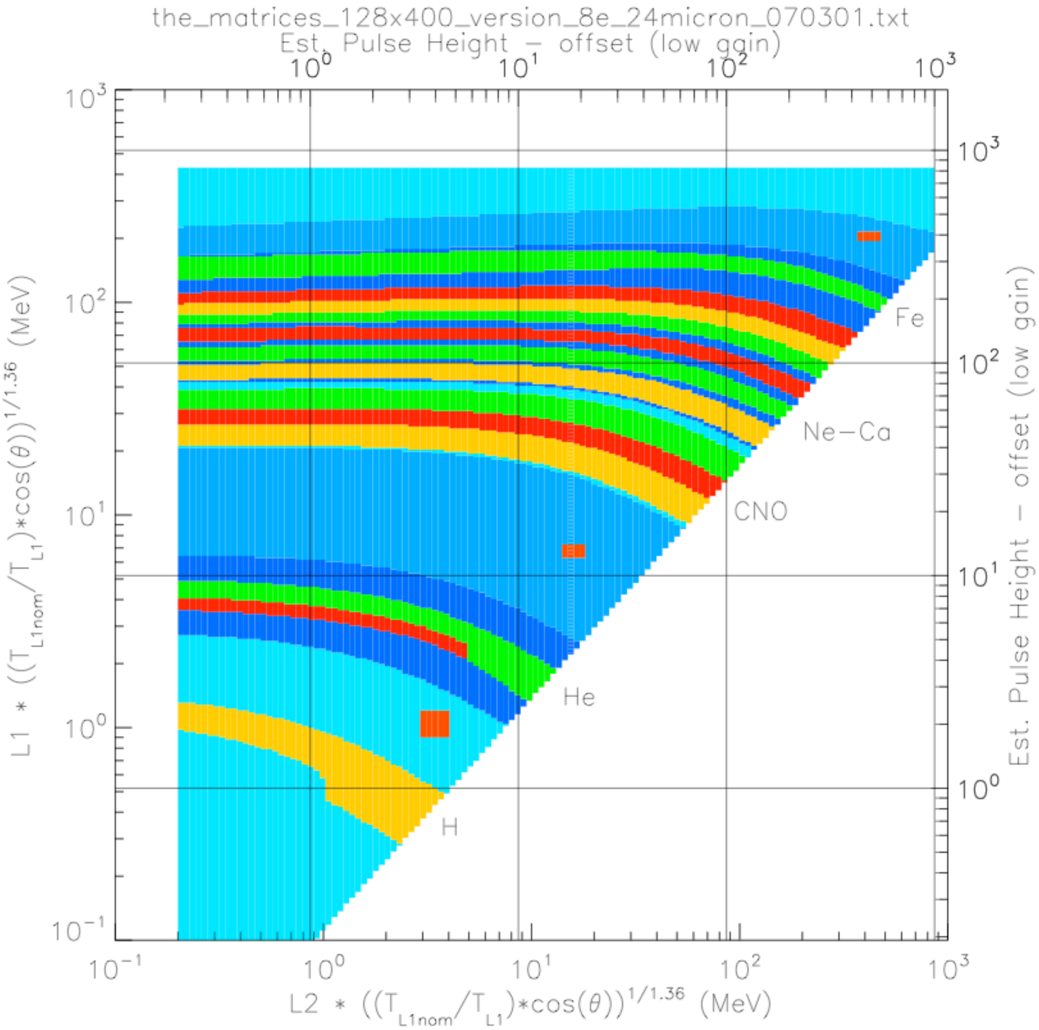


Figure C.1: The Range 2 (L1 vs. L2, or L1L2) LET matrix. Foreground elements are H, He-3, He-4, C, N, O, Ne, Mg, Si, S, Ar, Ca, and Fe.

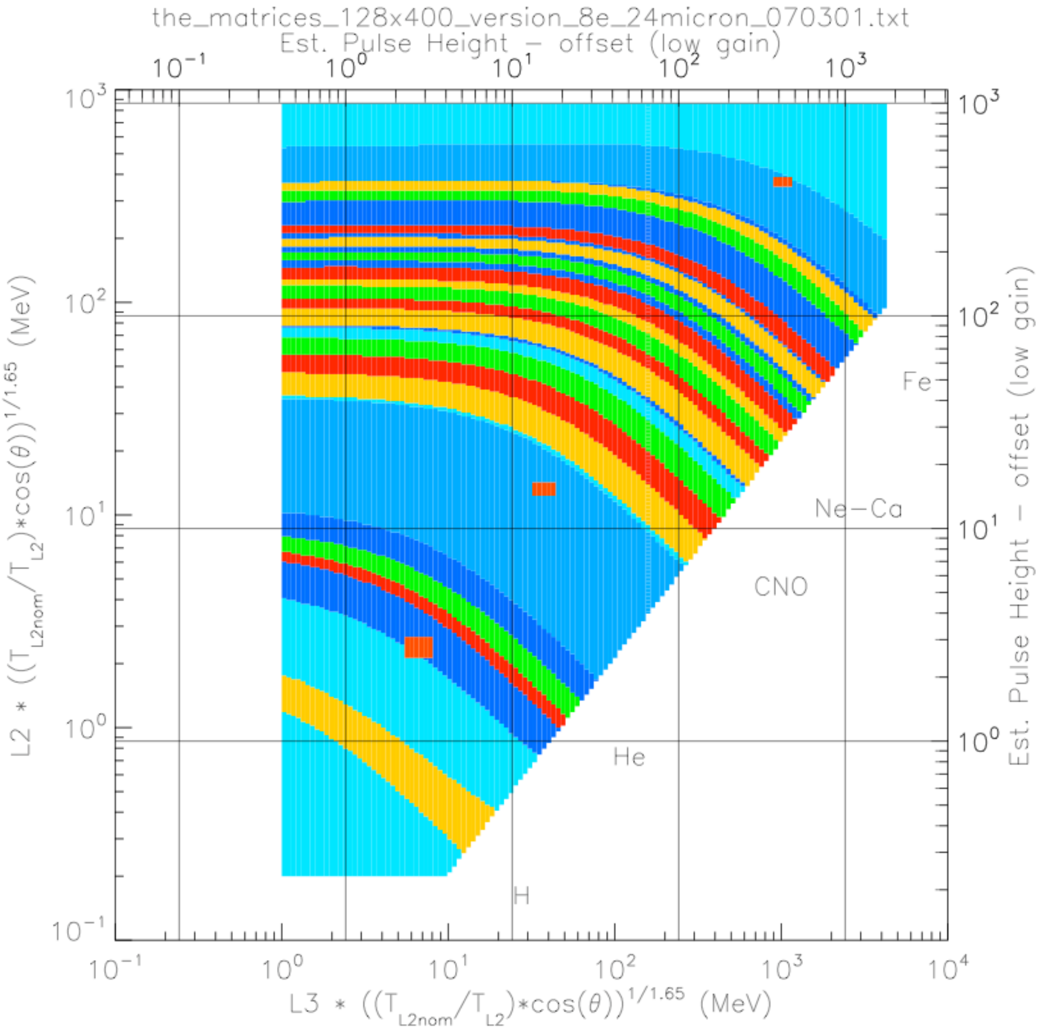


Figure C.2: The Range 3 (L2 vs. L3, or L2L3) LET matrix. Foreground elements are H, He-3, He-4, C, N, O, Ne, Na, Mg, Al, Si, S, Ar, Ca, Fe, and Ni.

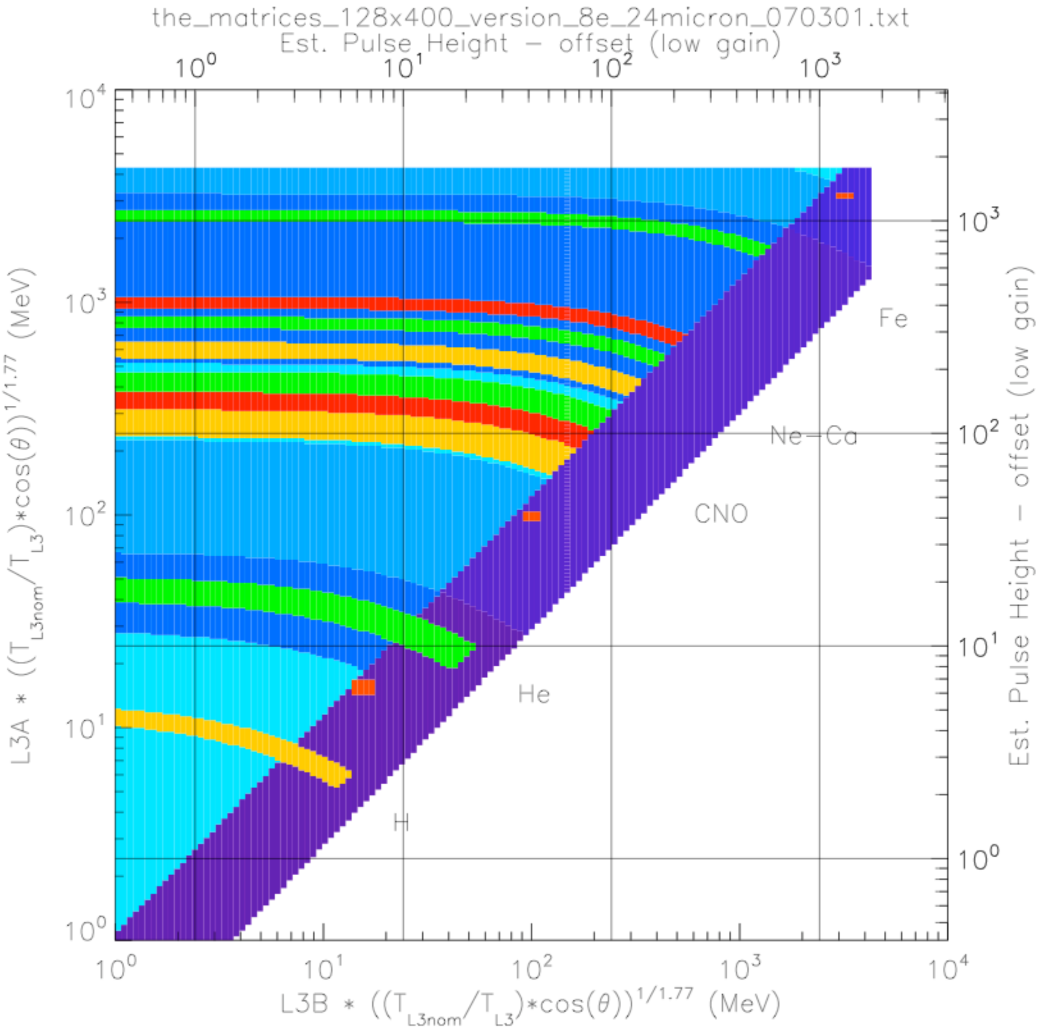


Figure C.3: The Range 4 (L3A vs. L3B, or L3AL3B) LET matrix. Foreground elements are H, He-4, C, N, O, Ne, Mg, Si, and Fe. The dark diagonal regions mark penetrating particles (or RNG 5).

Appendix D: Version History

1.0

Original

1.1

In version 1.0, we assumed 6 energy bins and 3 species bins (H, He3, and He4), with 16 bits per lo-res rate. These assumptions yielded 36 bytes of lo-res rates per LET Science Frame. These were increased to 4 energy bins for H and 5 species bins and 8 energy bins for He, or a total of 88 bytes of lo-res rates per LET Science Frame.

In version 1.0, we assumed 8 energy bins and 7 species (C, N, O, Ne, Mg, Si, and Fe), also with 16 bits per rate. These assumptions yield 112 bytes, divided among 15 LET Science Frames, for 7-8 bytes per frame. Assume 8 bytes per frame, with the 15th frame having a blank 8 bytes which can be used for other data, such as lo-res diagnostics.

In version 1.0, there were 44 detector segments, requiring 6 bits for detector IDs. In version 1.1, there are now 54 detector segments, with L1 detectors now having two outer ring segments instead of one. However, only 6 bits are still required.

2.0

Add LET Science Frame Header.
Add LET Science Frame Format Summary Table.
Add note about possible bit errors in the Event Buffer. This may require further revision.

3.0

Switch lo-res rates to hi-res rates — consolidate all rates. “1 minute for H, He; 15 minutes for Z≥6” becomes “1 minute for all species”. Given that the rates are now no longer divided into low and high resolution rates, the 15 minute cycle is now eliminated. Lo-res and hi-res rates are now designated as science rates (or species).

Switch rates to 16 bits, log-compressed.

4.0

Add appendix showing compression/decompression code.
Update bit rate allocation (or LET Science Frame size) for LET, up to 16 CCSDS packets/minute.
Reduce data transmission rate to once every 3 seconds.
Add K, Ar, and make Mg be in 3 charge bins.
Fix # species in Table 1.
Add look direction.

4.1

Removed minor frame structure, replacing minor frames with full CCSDS packets.

4.2

Add HAZ and STIM bits (replacing default 0’s) to event record headers.

5.0

Migrate master document to Microsoft Word X for Mac OS X format (from Appleworks 6).

Remove reference to Phase A Study Report; it is superceded by more recent documentation and discussion.

Add singles rates.

There is now a single byte checksum at the end of each CCSDS packet, which takes away an additional byte per CCSDS packet.

Modified frame header to include count of # CCSDS packets and # bytes in frame.

Rewrite Event Record Header to eliminate L1 vs. L2+L3 index (obsolete), add Good/Bad flag and # hits and # adcs.

6.0

Add sections on byte order, ApIDs.

Change singles rates to include both low and high gain singles rates – doubling the number of singles rates and eating into the Event Buffer.

Rewrite section on TBD undetermined space and change it to housekeeping space.

Add special STIM event format.

Switch to 4 bit exponent in compression algorithm.

Various corrections to errors in the text.

7.0

Update references to STEREO-CIT-002.F from version E.

Add reference to STEREO-CIT-007.F.

Remove Ne isotopes as a requirement from Table 1. It is still a goal.

Add a spacecraft/source/version ID byte to the header – this despite the fact that spacecraft id will be on all packets or somesuch according to Dave Curtis. (Section 2.3)

Correct an error in the byte numbering in the LET Science Frame Header (Section 2.3).

Corrected an error in the text of Section 2.6 which stated that there will be 60 singles and coincidence rates. Tables 17 is correct.

Define a numbering scheme for the look direction sectors.

Add livetime definitions to the housekeeping. (See Appendix B – do we need a DPU livetime?)

Fixed a bunch of table reference errors.

Added extra information to the format summary tables.

Rename Appendix B (this appendix) as Appendix C, and insert a new Appendix B for "outstanding issues".

Modified compression algorithm to 12 bit mantissa, 4 bit exponent. (Appendix A.)

Slightly modified definition of Particle ID (Section 2.4) to match the fact that the Event Record Header (Section 2.8) now assigns only 8 bits instead of 9 (in version 6).

Updated the Event Record Header to the final result from discussions and e–mails around September 11, 2003. Also updated text with event record header discussion.

Added look direction definitions, and inserted a new table 7.

Switched the order of charge bin and energy columns in Tables 3-6, to reflect the now-explicit ordering by range, element, charge bin, and energy in the text. (I may have swapped charge bin and energy ordering when I previously discussed this with Bob Radocinski.) This ordering reflects the way the L1L2, etc. matrices will be straightened out to species vs. energy, so that ordering will first be along the y-axes (element, charge) then along the x-axes (energy).

Added revised livetimes. Note that livetime counters now take up 130 bytes, filling the housekeeping section.

8.0

Extensive rewrite based on software meeting of 1/8/04.

Rewrite goals (Table 1) to drop Ne and Mg isotopes — no longer possible with 128x400 LET Matrices. Only He-3 and He-4 isotopes are in rates data.

P. 1: The 11 byte header and 1 byte checksum for each 272 byte CCSDS packet are not included in the LET Science Data Frame Format.

Rewrote Section 2.2 ApIDs. A single ApID (580) is assigned to the entire frame. Individual packets are numbered in the subsecond field bits of the CCSDS packet headers.

Added Section 2.10, Miscellaneous Bits and Rates (TBD).

Remove references to isotopes other than He-3 and He-4 throughout this document. The LET rate matrices will not accomodate Ne and Mg isotopes as of this version.

Appendix C (Version History) now shifted to Appendix D, and Appendix C inserted for LET Matrices.

Renumber tables in X.Y form, where X is section number. Fixed figure numbering as well.

In Section 2.9 (formerly Section 2.8), 2nd paragraph, the 438 2-ADC events in the buffer space is in error, left over from version 4 of this document, in which the Event Buffer was 3506 bytes long. Update this number, finally, to the correct value of ~303 for the current format.

Expand the Event Record Header format to 4 bytes based on R. Mewaldt's memo of 10/23/03 and A. Davis' e–mail of 1/21/04, adding the addition byte to the header and swapping the order of STIM and HAZ bits.

Updated a lot of numbers, including # events per frame.

9.0

Swap byte order (section 2.1) to high byte first. Correct example in Section 2.1 to reflect 4 bytes in event record header.

Swap byte order of table columns in Section 3.

Modify Figures 2.4, 2.5, and 2.6 to reflect the new byte order.

Change text in a couple of spots to reflect the new byte order.

Replace column headings "Frame Byte # (Low)" and "Frame Byte # (High)" in Section 3 with "Frame Byte # (First)" and "Frame Byte # (Last)" in order to avoid confusion, since data elements are transmitted high byte first.

Expand time tag (Latency tag in ERH) to four bits, and modify table 2.2 and figure 2.2 accordingly. Insert blurb about extended header, missing from previous version.

10.0

Named coincidence rates, and added 2 "spare" coincidence rates.

Fixed text error on p. 3. Rates occupy ~5.5 packets, not ~4.5 packets.

10.1

Fixed naming of NUMACCPHA and NUMACCNPHA in Table 3.3.

11.0

"Elements to be resolved or to be determined, or elements documented only in software, are marked **TBD" to acknowledge a lot of software already written but not documented here or likely elsewhere.**

Section 2: The LET Science Data Frame Format will now "attempt to" accommodate goals listed in Table 1.1. Some telemetry goals may be affected by the inclusion of optional information blocks in event records.

Science Frame Byte 0 (Science Frame Header, section 2.3) now gives the two most significant bits to identify the EM unit, FM1, and FM2. The remaining bits are still the LET Science Frame Version (#11).

Section 2.8: MISCBITS are now defined, at least with software tag names. I don't have documentation on the functions. MISCRATES are still left blank as of this version.

Defined bits 30 (STIM block flag) and 31 (culling flag) in the Event Record Header (ERH), Table 2.2, Section 2.9. Also updated Figure 2.2.

Section 2.10: Fixed figure 2.6 for a 3 byte STIM information block. The figure originally showed a 2-byte block. Added information on the STIM information block, as extracted from Bob Radocinski's letevent__define.pro code. However, the exact arrangement of bits can't be determined from that code, so this information is imprecise at this moment.

Added Section 2.11 Extended Header Block. I assume it's 2 bytes and contains only DEINDEX and EPINDEX, based on Bob Radocinski's software, but as with the STIM information block, I'm not sure of the precise configuration.

Section 3.0, updated tables 3.1, 3.2, 3.6,3.8, 3.9, 3.11, 3.13, and 3.15.

Updated matrix plots (Appendix C) to version 6.

12.0

After e-mail discussion I had with Andrew Davis and Bob Radocinski, we determined that the onboard software doesn't match the format of the event record as described in version 11 of this document. In the software, the Extended Header block and STIM information block come after the ADC fields, and the extended header block is 16 bits. Bit padding (to fill out to byte boundaries) occurs at the end of the event record, after the optional blocks. Changed Figures 2.6 and 2.7 to match the format, and changed the t ext as needed (and where I found the text to be incorrect – some errors may yet remain).

Added some description of hardware counters to Section 2.7.

12.1

Section 2.2: Fixed error so that bits 0-3 of the subseconds field of the CCSDS packet header are replaced by the packet number (0-15), not bits 0-4. Was versin 12.0 in error? Or did we eventually allocate 5 bits in case we'd get to use 20 CCSDS packets?

13.0

Section 2.9 and Table 2.2: Fixed the definition and discussion of Latency Bits, based on analysis and discussions from the January 2007 time when I had thought that latency might provide a hint as to why Priority Buffer 24 was suddenly showing low count rates, as well as documentation detective work by MEW on 4/9/07. The Latency Bits are the 4 least significant bits of the minutes counter in MISCBITS. See my 1/18/07 e-mail and whatever else we sent around at that time; the data I plotted were on the Behind spacecraft, from 2007_017_1_05. (The problem was eventually traced to misplaced pointers onboard.) The new definition is also the same as that in the instrument paper, but in more detail.

Updated matrix plots (Appendix C) to Version 8e.