LET Flight Software

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11-14-2002

LET Software Requirements and Verification Matrix (1)

Description	Requirements	Verification
Power-on/Reset	Boot via serial link to SEP Central.	Verify successful boot. Verify RAM checksum after boot.
RAM Patches	Implement RAM patches uploaded by command from GSE.	Upload patch, write to RAM, verify checksum.
Command Interface	Receive commands and send responses via serial cmd link to SEP Central.	Send a standard set of commands and verify responses.
Science Data Acquisition	Acquire PHA events from front end. 1000/sec required, 5000/sec goal.	Generate events using radiation sources and ADC CAL pulses. Verify acquisition of event data.
	Each minute, acquire singles, coincidence rates from front end.	Generate counts and events using rad. Sources and CAL pulses. Verify acquisition of correct counts.

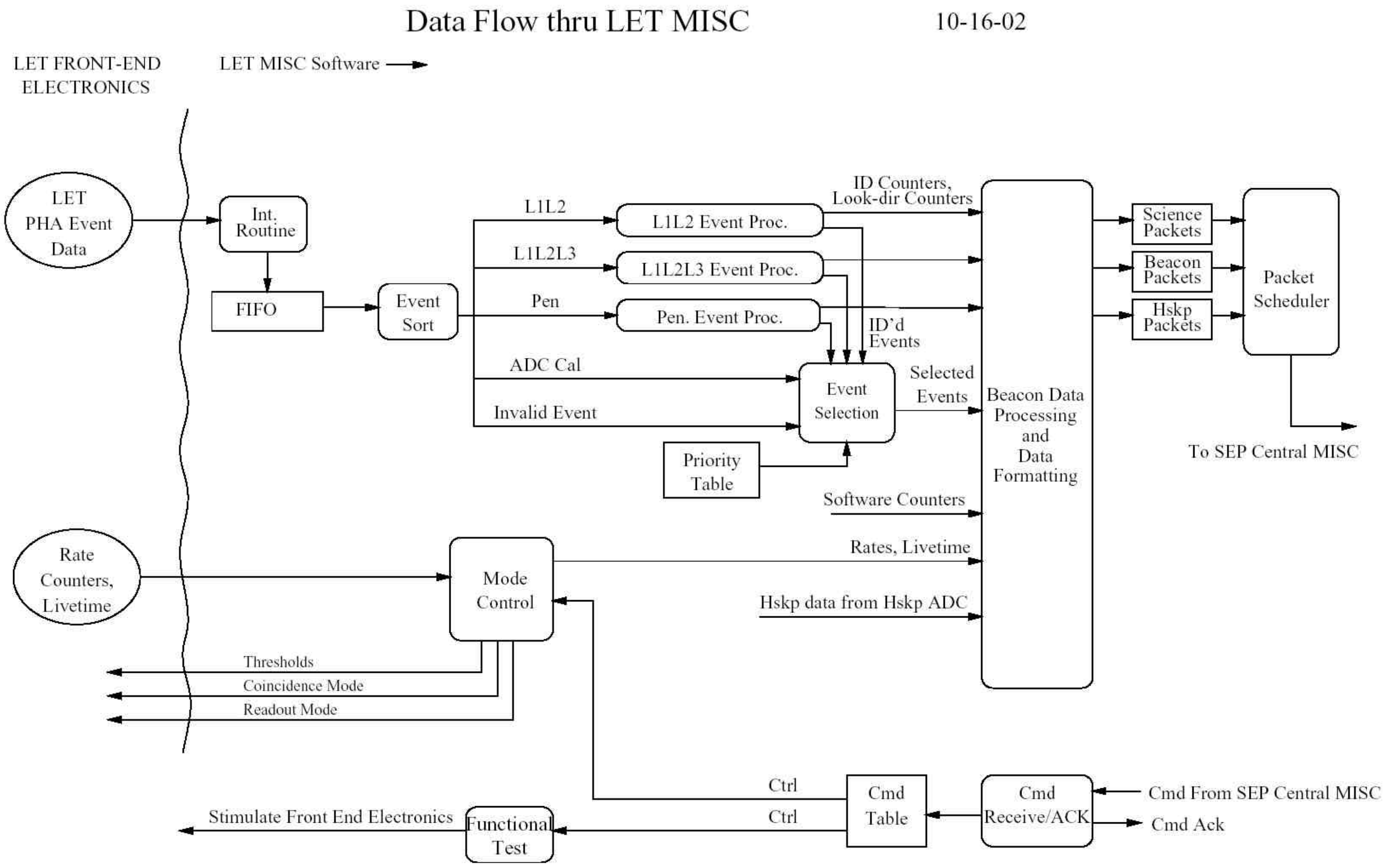
LET Software Requirements and Verification Matrix (2)

Description	Requirements	Verification
Housekeeping and status data Acquisition	Each minute, acquire housekeeping data (4 temperatures) from LET HK ADC.	Vary temperature at location of temp. sensors, and verify change in temperature data.
Refresh Command State	Refresh PHASIC status registers . (once per sec)	Read and verify status registers after each refresh.
Science Data Processing	Assign particle ID to PHA events. 1000/sec required, 5000/sec goal.	Use ADC CAL pulses and LET simulation data as input to onboard processing routines. Verify output.
Beacon Data Processing	Each minute, extract beacon data subset from science data.	Use LET simulation data as input to onboard processing routines. Verify output.
Data Formatting	Each minute, format LET science and beacon data into 272-byte CCSDS packets.	Stimulate LET using radiation sources, ADC CAL pulses, simulation data. Verify telemetry data.

LET Software Requirements and Verification Matrix (3)

Description	Requirements	Verification
Data Formatting (continued)	Each minute, format LET housekeeping data into one CCSDS packet	Vary temperature at location of temp. sensors, and verify change in temperature data. Monitor contents of housekeeping data.
Transmit Data to SEP Central	Each minute, transmit 16 science, 1 beacon, and 1 HK packets to SEP Central via serial data link.	Stimulate LET using radiation sources, ADC CAL pulses, simulation data. Verify telemetry data.
Dynamic Threshold Adjustment during high count-rate periods	Disable/enable high-gain response on some L1, L2, L3 detectors depending on count rates.	Stimulate LET using radiation sources, and ADC CAL pulses at varying rates. Verify telemetry data.
Periodic Functional Tests	Livetime Monitor.	Stimulate LET using radiation sources, ADC CAL pulses. Monitor telemetry.
	ADC Functional Test.	

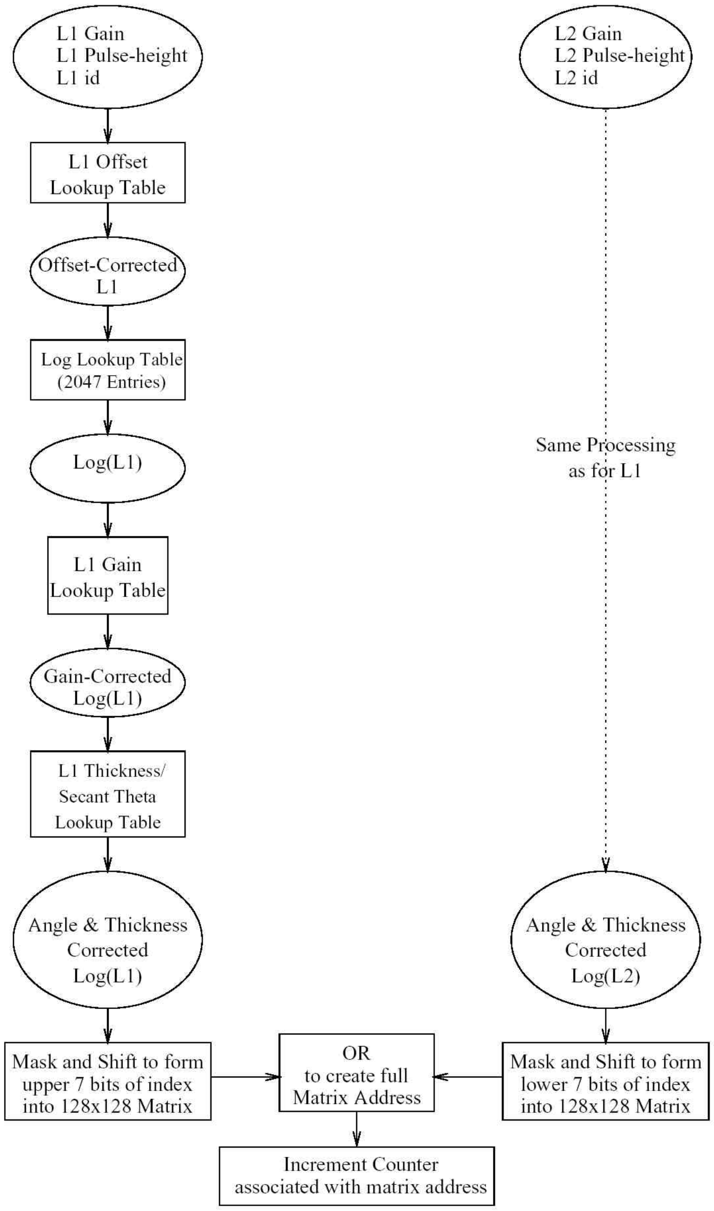
LET Flight Software Functional Flow Diagram



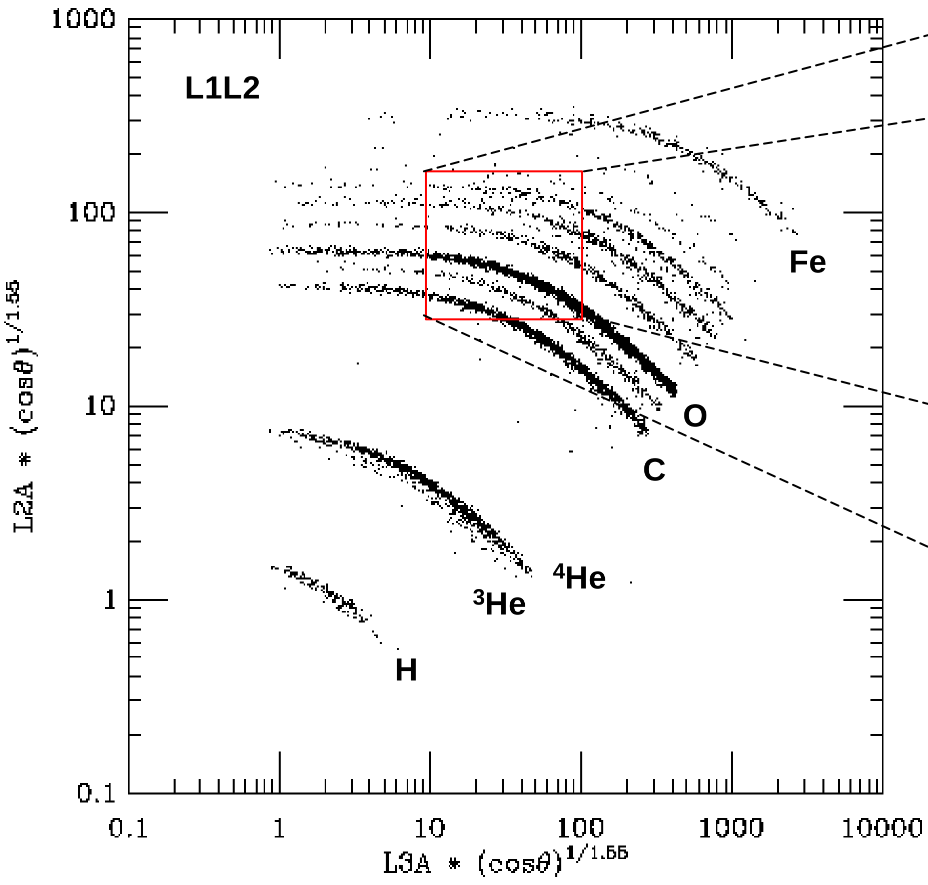
LET Event Processing Summary

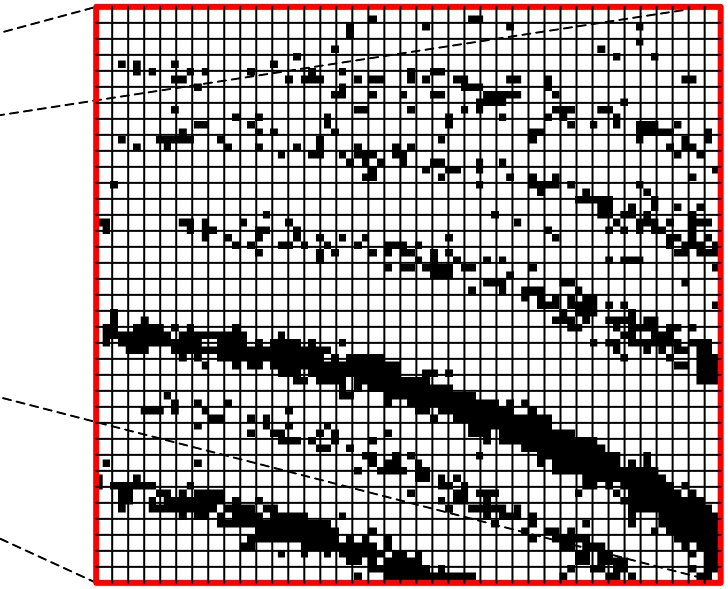
1. **Sort the event into several streams: L1L2, L1L2L3, Penetrating, ADC cal and Invalid events. Invalid events are unsuitable for onboard processing. The sort criteria will be changeable by command.**
   - **Examples of invalid events: ADC overflows, out of geometry events**
2. **For valid, non-ADC cal events, determine the charge and kinetic energy of the particle by mapping the event data into a 2-dimensional detector response matrix. Increment a matrix rate counter associated with the species and energy-range determined.**
3. **ADC cal events are not processed onboard, but are queued for telemetry with high priority.**
4. **For selected classes of good events (class determined in step 2 above), determine look-direction and increment the appropriate look-direction counter.**
5. **Select events for telemetry based upon a priority scheme. The priority scheme will be changeable by command.**

LET L1 vs. L2 Event Processing
10-16-02

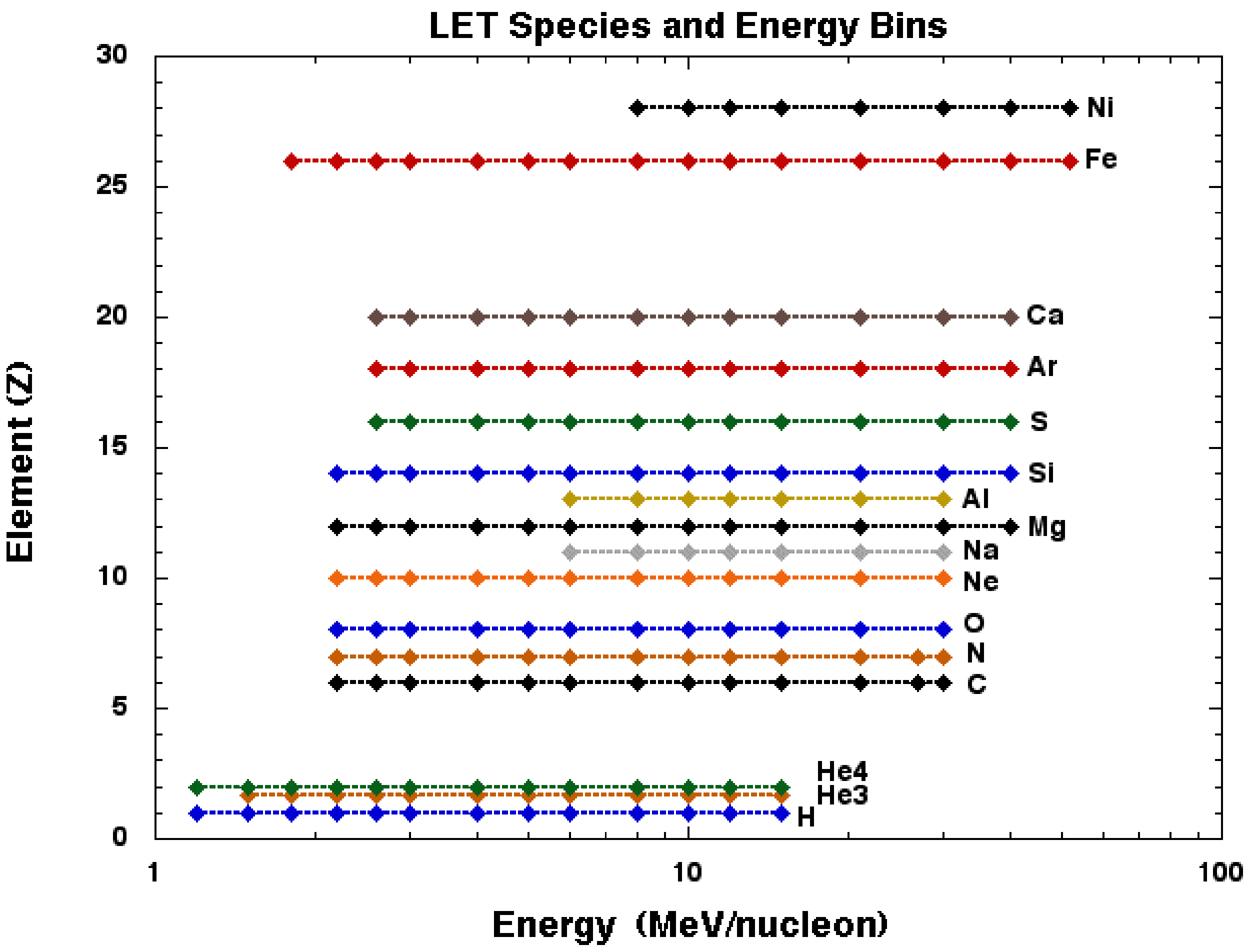


Particle Identification by LET Onboard Event Processing





The matrix cells shaded green all contain the address of the same counter. This counter counts oxygen in a certain energy range.


LET Species and Energy Bins
Element (Z)
Energy (MeV/nucleon)
0
5
10
15
20
25
30
1
10
100
Ni
Fe
Ca
Ar
S
Si
Al
Mg
Na
Ne
O
N
C
He4
He3
H

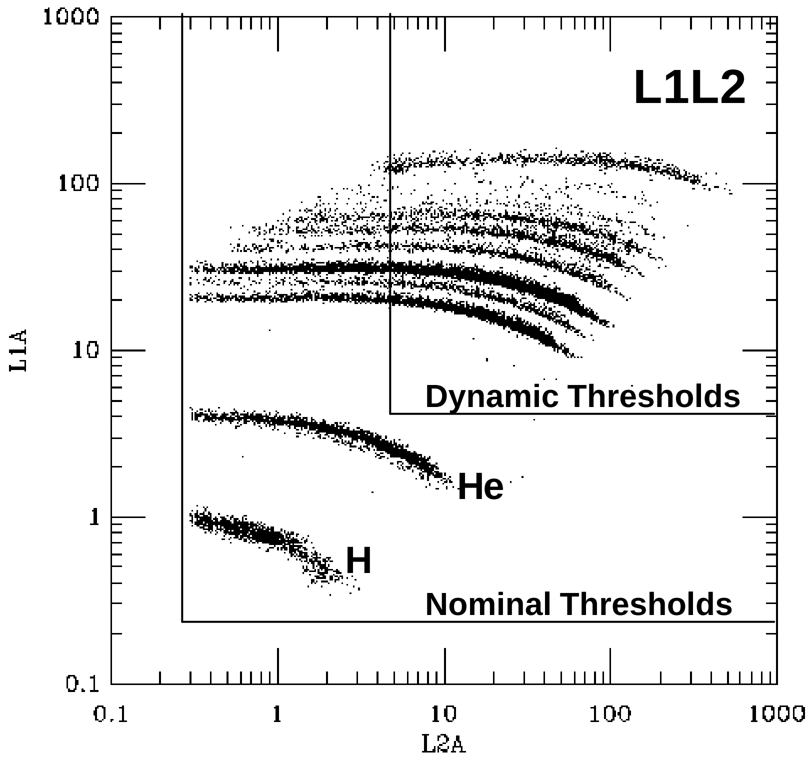
LET Dynamic Response to High Rates

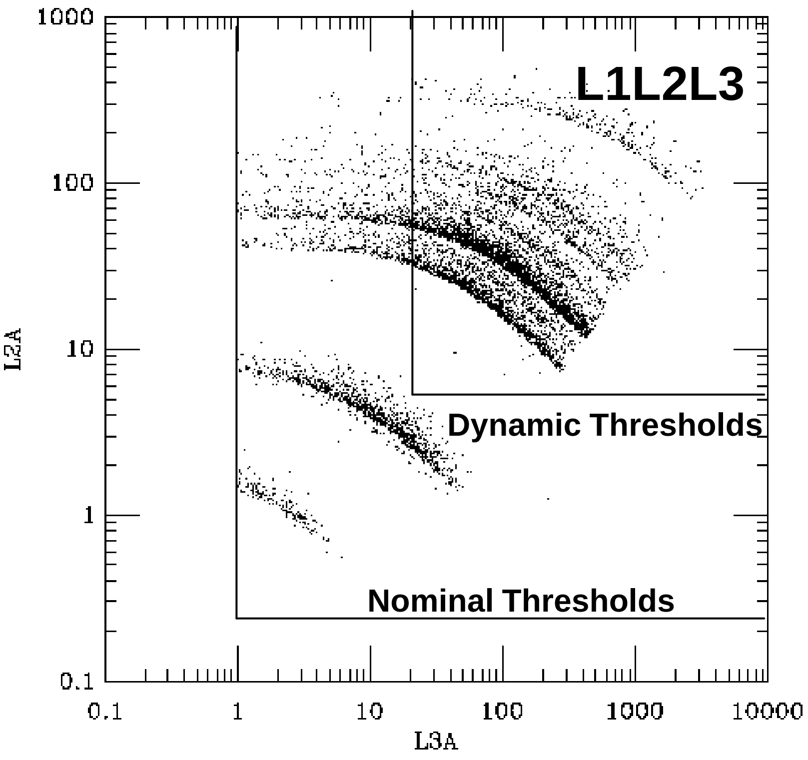
- During very high-rate periods (e.g., peak of Bastille Day 2000 event) the single-detector count rates, especially on the front detectors, can exceed 10^5/sec, mostly due to out-of-geometry, wide-angle protons.
- LET will respond dynamically to high rates by disabling the high-gain PHA response on a fraction of the L1, L2, and L3 detectors, such that these detectors will trigger only on heavy ions and not on the much more abundant H and He ions.
- The geometry factor for protons and helium will therefore be reduced, while the geometry factor for the more rare heavy ions will be preserved (heavy ions deposit more energy in the detectors, thus triggering the low-gain PHA chain).

LET Dynamic Response to High Rates (continued)

- **The high-gain response will be disabled in steps, depending on the "OR" of count rates from detectors that are not adjusted (L1A3, L1B3, L2A5, L2A6, L2B5, L2B6, L3Ai, L3Bi), as follows:**
  1. **All L1 outer segments (reduces H, He geometry by x5 and singles by x5).**
  2. **All L2 detectors except L2A5, L2A6, L2B5, and L2B6. Also L3A outer, L3B outer (reduces H, He geometry by additional ~x5 factor)**
  3. **All L1 inner bulls-eye segments except L1A3, L1B3 (reduces H, He geometry & singles by additional ~x5 factor).**
- **The implementation of the algorithm will adhere to the following requirements:**
  – **Parameters will be modifiable by ground command. In particular, the count rate trigger for re-enabling high-gain response shall be modifiable separately from the count rate trigger for disabling the response. The averaging periods for determining these count rates shall also be modifiable.**
  – **It will be possible to turn off dynamic thresholding via ground command.**
  – **Changes will occur on sensible time boundaries (e.g. on 1-minute LET science frame boundaries).**
  – **The dynamic threshold function will be tested on the bench before flight using pulsers and radioactive sources, and will also be tested during accelerator tests.**

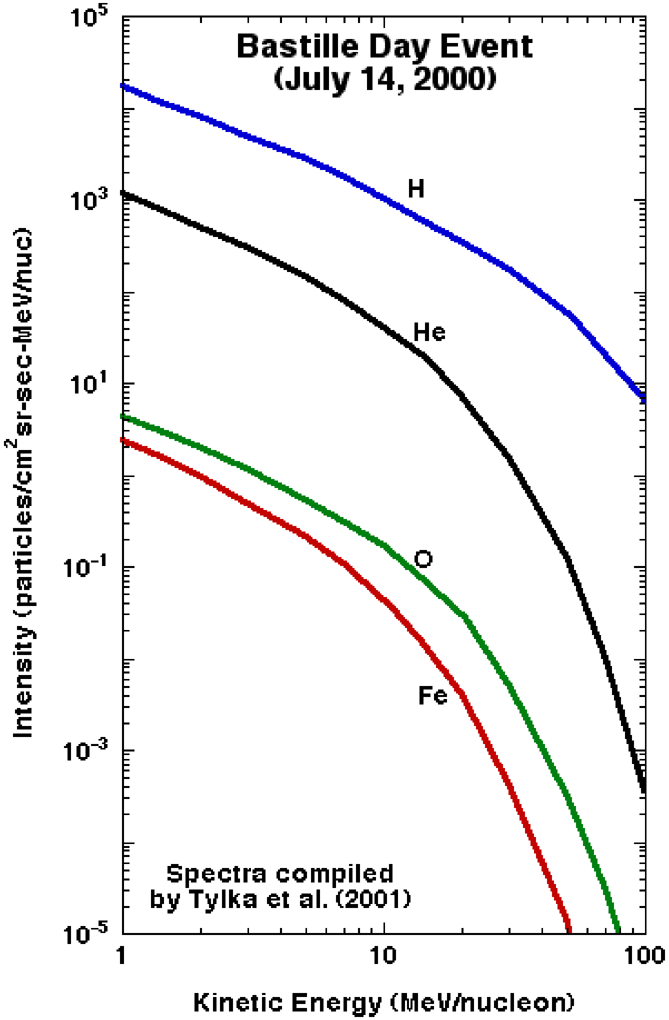
LET Raw Data without Onboard Angle Corrections





By disabling the high-gain discriminators on a portion of the ADCs during high-intensity periods the geometry for H and He can be reduced by up to a factor of ~100 while retaining most of the geometry for heavy ions

LET Performance at High Count Rates



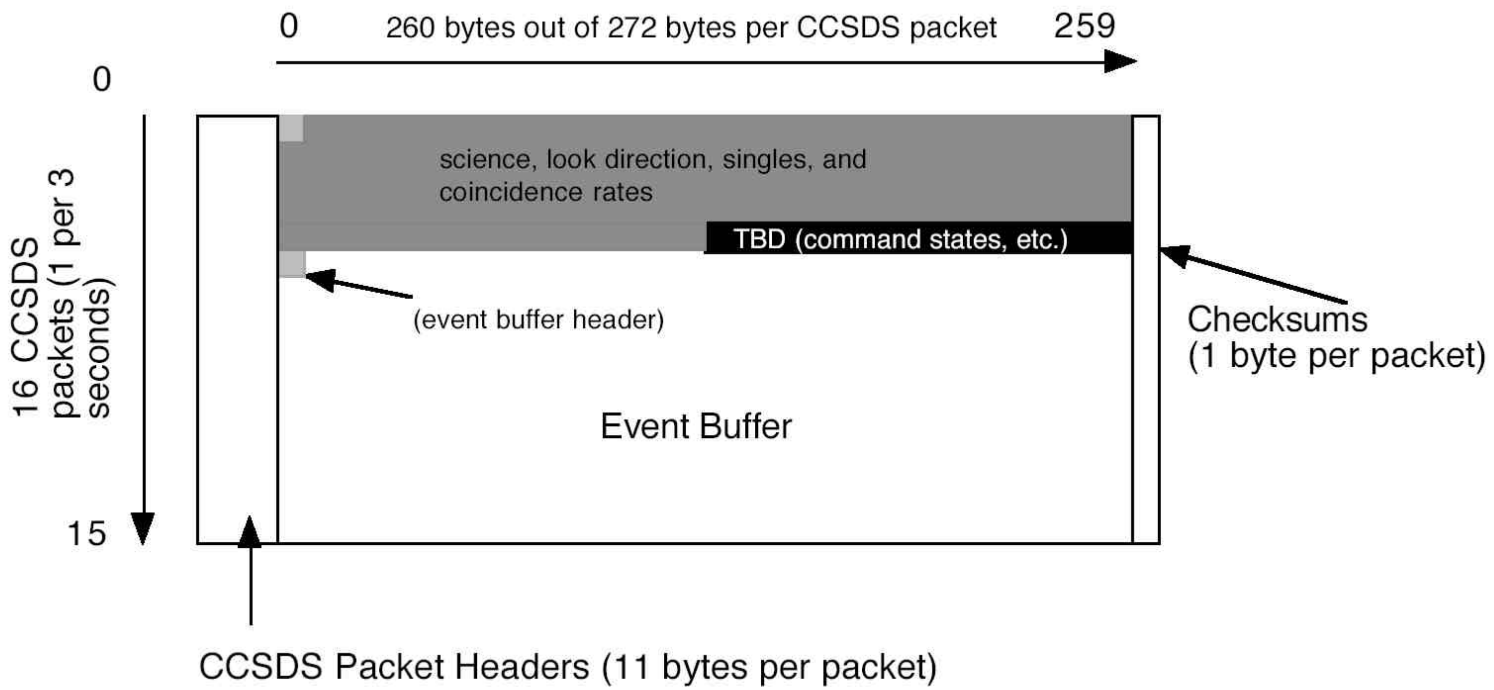
Estimated count rates for the largest SEP event of Solar Cycle 23

	Events per Second	
Species	**Normal Thresholds**	**Dynamic Thresholds**
H	133,000	1770
He	7,650	120
Z=6	60	55
Z=10	28	26

Preliminary Priority System for Event Telemetry

	Priority System					
	Clean			Multiple Detector		
Species	L1L2	L1L2L3	PEN	L1L2	L1L2L3	PEN
H	18	17	19		22	24
He	15	14	16		21	23
3=Z=8	8	7	13		10	
10=Z=30	6	5	12		9	20
Z>30	2	1	11		3	
CAL		4			25	
Other		19			26	
Reject			27			

LET Data Format – Details in LET Data format Document



LET Science Data Frame -- shown with CCSDS packet headers and checksums (not to scale)

LET CPU and RAM Resource Margins

Task	Processor Cycles, %	Code Size, kwords*	Buffer Memory, kwords*
Operating System	1%	2	2
Data Acquisition	5% @ 5000/sec	2	1
Event Processing	45% @ 5000/sec	6	42
Data Formatting	1%	1	1
Command Processing	1%	2	1
Total	**53%**	**13**	**47**
Available	100%	128kwords	
% Usage	**53%**	**47%**	
Margin	**88%**	**112%**	

*Note: for the MISC, one word = 3 bytes

LET Interrupt Handling

Interrupt	Max. Time to Begin Service	Max. Service Execution Time	Max. Rate	Synchronicity
Cmd rec'd	3 ms	10 us	~ 300/sec	ASYNC
Reply sent	~ 1 ms	10 us	~ 5000/sec	ASYNC
Event ready	---	20 us	~ 5000/sec	ASYNC
Timer Done	~ 1 ms	500 us	100/sec	SYNC
Data sent	170 us	10 us	~ 5000/sec	SYNC
Frame sync	1 ms	10 us	60/sec	SYNC

LET Flight Software Status

- ✓ Definition of requirements (*LET Software Reqs doc*)
- ✓ Definition of interface with SEP Central (LET-SEP_Central *ICD*)
- ✓ Forth OS and multitasking environment written and tested
- ✓ Low-level routines for interfacing with LET PHASIC chip are written and tested
- ✓ Several prototype versions of LET onboard processing software are written and tested. 11,000 events/second processed, with MISC running at 8 MHz (goal = 5000/sec)