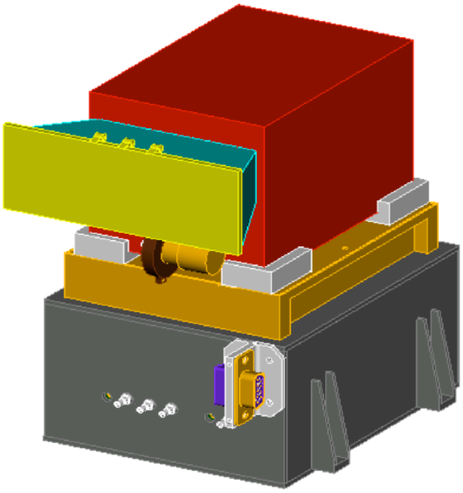
Design Considerations for the STEREO / IMPACT / SEP / Suprathermal-Ion-Telescope (SIT)



SIT - Supra Thermal Ion Telescope

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Modification history:

Version	Date	Changes
1.0	May 8, 2000	Original version by Joe Dwyer
2.0	June 14, 2002	Updated version, taking account MISC processor; data packets; instrument design changes, etc.
2.1	June 25, 2002	Show PHA event bit assignments; show sample lookup table values in hex as well as decimal; modify lookup table bit assignments; change 1/7 divide in lookup calc to (1/8+1/64)
2.2	April 15, 2003	1) Since packet IDs in CCSDS header APID, rearrange PHA and RATE packets (appendix 7 and 9) 2) Add appendix 6 with list of APID assignments
2.3	August 23, 2004	1) fix errors in Table A7-1 (Rate packet contents) per Tom Nolan e-mail of Oct 13, 2003; MR116 had been shown in wrong cells; this changed, and other following cells adjusted accordingly. 2) add full description of all rate packets 3) add CCSDS header description; rate decompression algorithm 4) change SSD threshold in Table 1 to 100 keV 5) add rate decompression algorithm; HK conversion factors
2.4	Sept 1, 2004 ff	1) put actual fm1 HV conversion in Table A-15 2) modify SSD threshold in Table 1 3) add APID 577 and 624 formats 4) add checksum table 5) 12/17/04 added notes to HV analog cal 5) 1/12/05 minor changes prior to Pre Env review
2.5	June 9, 2005 ff	1) adjust HK algorithms, Appendix 15 2) add UMd GSE Winmac hex file byte assignments in packet description tables

1. Introduction and Acknowledgements

The Suprathermal-Ion-Telescope (SIT) is part of the In-Situ-Measurements-of-Particles-and-CME-Transients (IMPACT) investigation on board the STEREO spacecraft. Each SIT sensor is a time-of-flight (TOF) mass spectrometer, designed to measure the ions, protons though iron, from ~20 keV/nucleon up to several MeV/nucleon in energy.

In-situ observations of solar and interplanetary energetic particles help us understand the important processes involved in the acceleration and transport of energetic particles. Since energetic particles are produced throughout the universe, these processes are relevant not only in the heliosphere but also in more exotic, astrophysical sites, where in-situ measurements are not possible.

SIT is designed to measure energetic particles produced by a wide variety of phenomena, including particles accelerated by CME driven shocks in the solar corona and in interplanetary space, solar flares, and corotating interaction regions (CIRS). Because the shocks associated with CMEs are often quite weak at 1 AU, the energy spectra produced by these shocks are usually soft and do not extend into the MeV energy range. The large geometry factor (0.3 cm^2 sr) and low energy response of SIT, therefore, makes it well suited for observing energetic particles produced locally by these events.

Another advantage of SIT is that good mass resolution allows the composition of the particles to be measured, thus helping to determine the source population of the particles. Composition measurements, for instance, are useful in distinguishing particles that are accelerated in the corona, in interplanetary space, or at the site of solar flares.

This document gives an instrument overview and discusses design considerations for the Suprathermal-Ion-Telescope. Because the SIT sensor is nearly identical to the Supra-Thermal-through-Energetic-Particle (STEP) sensors, on board the WIND spacecraft, much of the information given below was determined using flight data acquired by STEP (von Rosenvinge *et al.*, *Space. Sci. Rev.*, 71, 155, 1995).

We wish to acknowledge the many individuals who contributed to the development of the SIT hardware and flight software, in particular: at GSFC: Sandy Schuman, and Bert Nahory (hardware, SSDs); George Winkert (firmware); Kristin Wortman, Tom Nolan, and Haydar Teymourlouei (software); at MPS: Klaus Heerline (TOF development); at the Technical University of Braunschweig: Christian Dierker (DTOF development).

2. The SIT sensor

2.1. Instrument overview

Figure 1 shows a schematic diagram of a SIT sensor. There is one SIT sensor on board each of the two STEREO spacecraft. A Valid Event is produced when an energetic ion passes through the front foil of the telescope. Secondary electrons, produced by the foil, are electrostatically directed into the "Start" multi-channel plate (MCP). The signal from the Start MCP provides the trigger for the time-to-amplitude-converter (TAC) electronics. Meanwhile, the energetic ion traverses the telescope and hits the solid-state-detector (SSD) at the back. In the energy range measured by SIT, the ions are stopped by the SSD, and, consequently, the kinetic energy is completely absorbed in the detector. In addition, when the incident ion strikes the SSD, it liberates more secondary electrons, which are then electrostatically directed into the "Stop" MCP. The signal from the Stop MCP provides the necessary coincidence for the TAC to measure the time-of-flight (TOF) of the ion.

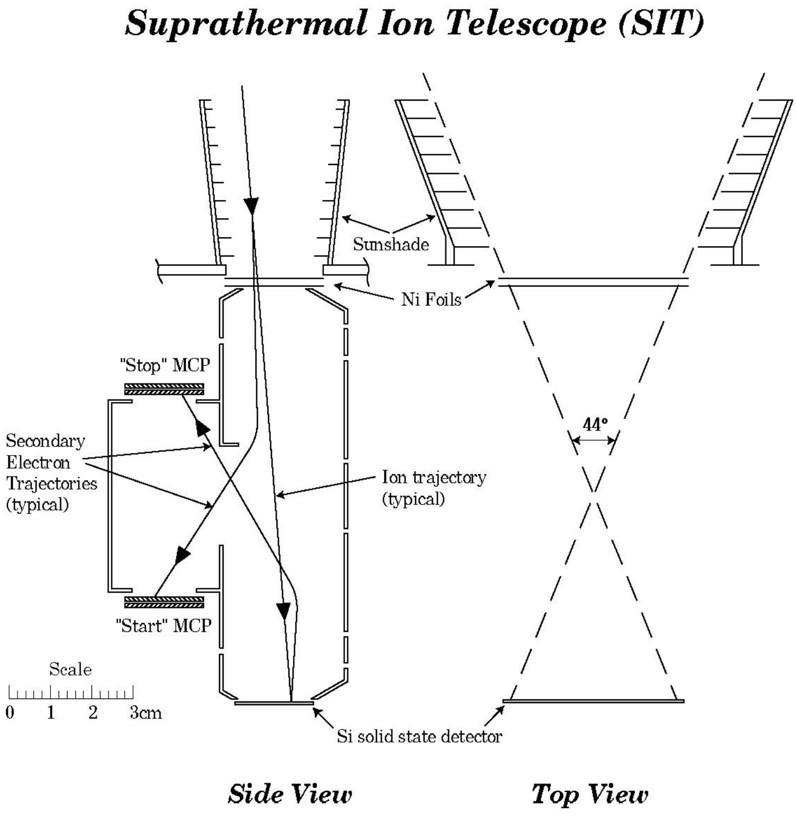


Figure 1. Schematic diagram of the sensor for the Suprathermal-Ion-Telescope (SIT).

By measuring the TOF from the TAC and the total kinetic energy from the SSD, the atomic mass and kinetic energy per nucleon of the incident ion is then determined (after energy loss corrections in the front foil and the SSD detector window) using the familiar equation for the kinetic energy

$$E = \frac{1}{2}mv^2 \tag{1}$$

Here E is the total kinetic energy from the SSD, m is the atomic mass of the ion, and v is the speed of the Ion. Solving equation (1) for m, and inserting constants including the 10cm flight path, we have

$$m = 0.021 * E * T^2 \tag{2}$$

where *m* is in AMU, *E* is the detector energy deposit in MeV, and *T* is the time-of-flight in ns. The constant 0.021 is based on a fits to a detailed (SITMR) calculation for Oxygen, and is approximately correct over a wide range of values but yields low masses for heavy ions and long times of flight.

2.2 Instrument Performance

As can be seen in equation (2), when *E* is plotted versus *T* on a log-log scale, the various atomic species organize themselves along straight tracks with slopes of -2 and offsets given by the atomic masses. This can be seen in figure 2, which slows pulse height analysis (PHA) data from the WIND/STEP sensors. The figure shows the TOF, measured in nsec, versus the total kinetic energy, measured in MeV. Each point represents the measurement of one solar energetic particle ion during the October 1995 event. As can be seen in the figure, the major species, p, He, C, O and Fe form distinct and well resolved tracks. The species Ne is partially resolved, and Mg, Si and S cannot be completely resolved by the instrument and are measured together as a group.

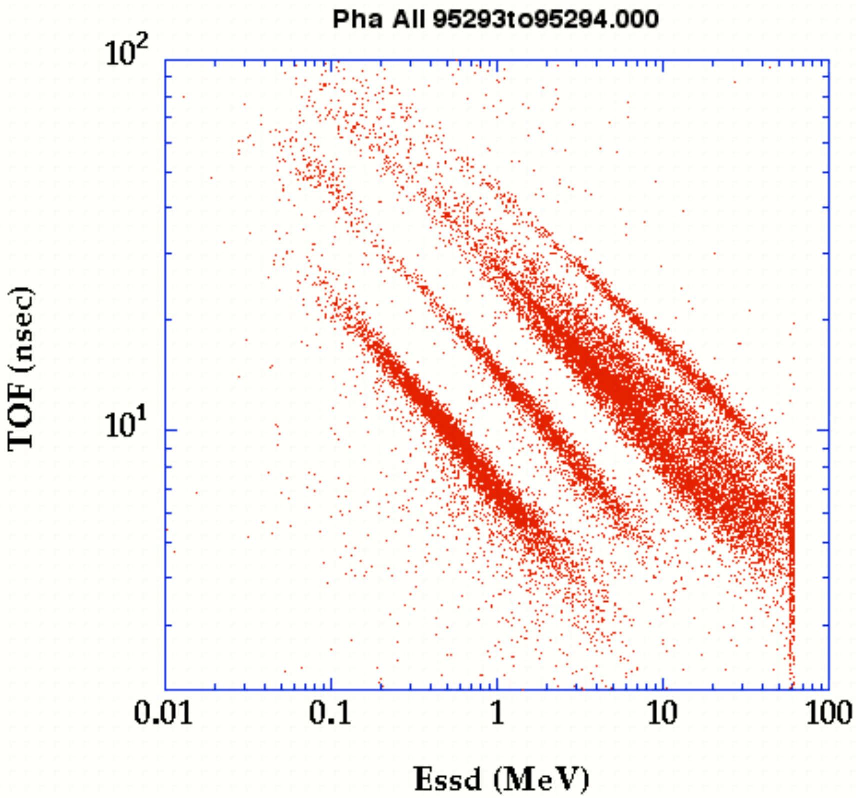


Figure 2. TOF versus the total kinetic energy for solar energetic particles, measured during the October 1995 event. The pulse height

analysis (PHA) data are from the WIND/STEP sensors. The SIT Essd values will extend up to about 160 MeV, considerably higher than in this figure.

2.3 Count Rates

Based upon over five years of interplanetary data from WIND/STEP, we have found that the Valid Event rate almost never rises above 1000 counts/second. Even large SEP events such as the November 1997 event only produce Valid Event rates of a few hundred per second. Furthermore, because of the geometry factor of the front foil and the low efficiency for measuring protons and helium, the Start MCP singles rate is typically about 300 times higher than Valid Event rate. We have found that with STEP, for Start rates higher than about 100,000 counts/second the gain on the Start MCP drops, thus reducing the efficiency for measuring the low Z species. We, therefore, consider 1000 counts/second to be an upper limit on the Valid Event rate for SIT. Correspondingly, the Start MCP singles rate will be less than about 300,000 Hz. The other singles rates, e.g. the Stop MCP and SSD rates, will be less than the Start rate.

3. Time-of-flight Electronics

For each Valid Stop event, the time-of-flight electronics provides a 9 bit TOF. The TOF for SIT ranges from approximately 3 to 130 nsec. The TOF electronics also produces the Start, Stop and Valid Stop discriminator rates, as well as a count of events with error conditions in the TAC.

4. Solid-State-Detector Electronics

The solid state detector must measure particle energies from 0.08 MeV up to approximately 163 MeV. Since the SSD PHA resolution is 11 bits, in order to reduce the dynamic range and improve the resolution at low channel numbers, the energy electronics, after the charge sensitive amplifier, has both a low gain (gain bit = 1) and a high gain channel (gain bit = 0). Every event is analyzed using both the low- and high-gain ramps; if the high gain ramp is not saturated (channel =<2047) then the high gain channel is used; if the high gain channel is saturated (channel 2047) then the MISC selects the low gain ramp.

Table 1. SSD amplifier gains

Gain	Ramp bit	MeV/channel	Threshold energy (MeV)	Maximum energy (MeV)
high	0	0.01	0.240*	20.48
low	1	0.08	20.48	163

*fm1 SSD threshold, Sept 04.

5. TOF and SSD Coincidence

The Valid Stop events from the TOF electronics and the events from the SSD electronics are checked for coincidences. These coincidences, called VSE, are the Valid Events for SIT.

6. Discriminator Rates

SIT has 8 discriminator rates listed in Table 2. These rates are generated in the TOF ACTEL, where they are counted in 16 bit counters, and read out to the MISC processor once per second. In the MISC the 1-s readouts are stored in 24 bit counters for a 60 s accumulation time. The maximum countable rate is limited by the bit storage in the TOF ACTEL, and is 65.5 kHz, except for #1 (Start TOF) which is prescaled by 8 and can therefore count up to ~0.5 MHz.

In the MISC, after the 60 second time intervals, the rates are then compressed from 24 to 16 bits, and put into the rate packet (Appendix 7).

The rightmost column of Table 2 shows the approximate maximum input count rate for each of the rate types, based on data from the Wind/STEP instrument during periods in 1995 when the spacecraft was in interplanetary space. It can be seen that the SIT accumulators can accommodate the highest rates observed on Wind/STEP. The listed highest Start and Stop TOF rates are in fact extrapolations of the actual observations, since at very high intensities, the MCPs saturate and the count rate for Start (and sometimes also the Stop) actually decrease with increasing intensity (this is verified by comparing these rates with the solid state detector, which does not exhibit this behavior.) If an accumulator in the TOF ACTEL fills, counts are no longer added to that accumulator so that “overflow” is prevented. As can be seen from the table, this will happen rarely, if ever, and in any case does not affect the science data returned during that period since the Matrix Rates (see below) are used to determine intensities.

Table 2. SIT Discriminator Rates

Rate Number	Name	Accumulation interval (sec)	Prescale	Maximum countable rate (kHz)	Approx. Maximum Input Rate (kHz)
1	Start TOF	60	8	524	300
2	Stop TOF	60	-	65.5	50
3	VS (Valid Stop)	60	-	65.5	1
4	SSD singles	60	-	65.5	20
5	VSE (Valid Event)	60	-	65.5	1
6	Dead time counter	60	-	65.5	64
7	Artificial STOP (TOF diagnostic)	60	-	65.5	1 (?)
8	TOF System Error Count	60	-	65.5	0.01

7. Data Processing

7.1 Rate Binning

In order to compute spectra with high time resolution, the PHA data is processed on-board into Matrix Rates that cover several species and energies. The procedure calculates pseudo-mass ("amass") and pseudo-energy/nucleon ("einc") from the measured time-of-flight ("tof") in ns, and total energy deposit in the solid state detector ("essd") in MeV.

For these quantities, we have the following approximate expressions:

$$\text{amass} = \text{essd} * 0.021 * \text{tof} \wedge 2 \qquad (3)$$

$$\text{einc} = 1 / (0.021 * \text{tof} \wedge 2) \qquad (4)$$

In terms of the values given in equations (3) and (4), the cell locations in the lookup matrix for pseudo-mass (f_m) vs. pseudo-energy/nucleon (f_e) are given by

$$\begin{aligned} \text{f\_m} &= (\text{alog}(\text{amass}) + 1) * (128/7) \\ &= (\text{alog}(\text{essd}) - \text{alog}(\text{einc}) + 1) * (128/7) \qquad (5) \end{aligned}$$

$$\text{f\_e} = (\text{alog}(\text{einc}) + 5.5) * 16 \qquad (6)$$

These expressions give values between 1 to 128 for particles of interest. For certain values of tof and energy, f_m and/or f_e will lie outside the allowed range, so the values require limit checking after the calculation. The choice of 128 bins for the f_m axis is based on the goal of separating C and O over much of the energy range, and ^{3}He and ^{4}He over limited portions of the energy range (e.g. the C and O track centers are separated by 5-6 cells over most of the range). The 128 bin size of the f_e array is required to allow reasonably close matching between the nominal energy bins (whose start energies are spaced by factor of $\sqrt{2}$) and the actual bins available on the f_e scale.

In order to carry out the calculation of f_e and f_m in the MISC, the above calculations need to be done as integers, and must further meet the condition that the 3-byte MISC words do not overflow in any part of the calculation—i.e. all intermediate terms must be less than 2^24 (16,777,216). The lookup tables used are listed in Table 3; additional details of the calculation are given in Appendix 1.

Figure 3 shows how the PHA data appear after being transformed to f_m and f_e coordinates, and the typical placement of various element bins for Matrix Rates. (Figure 4 shows the same PHA data with Beacon Rate bins; the data is simulated SIT data taken from Wind/STEP data shown in Figure 2.) Once the rate bin number is calculated, the corresponding rate counter is incremented, for both the regular rate bins, and also the Beacon Rates. Note that the priority bit, which is used in the PHA event selection, is not used for the rate counting. The rates are summed for 60s then transferred to a separate buffer for readout. A complete listing of the Matrix Rate bins is in Appendix 3, and the Beacon Rates are listed in Appendix 4.

Table 3. SIT lookup tables for event processing.

Lookup table	**Number of elements**	**Length (bytes)**	**Purpose**
1	2048	3	SSD ramp 0 channel → log(E)
2	2048	3	SSD ramp 1 channel → log(E)
3	512	3	TOF Channel → log(M/E)+constant
4	128 × 128	3	f(log(E)) and f(log(M)) → Rate box #, priority bit, and Beacon mode rate #
Total lookup table length:	20,992 elements (62796 bytes)		

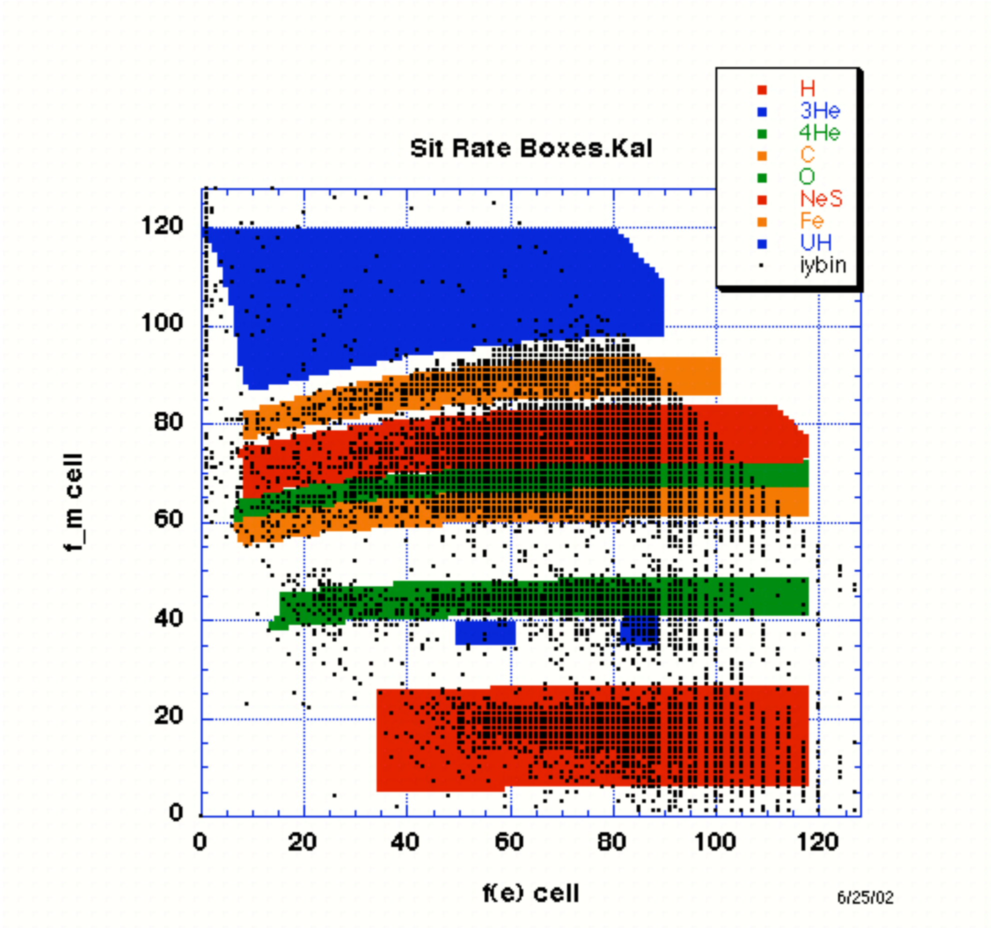


Figure 3. Valid Events (black dots) superposed on typical rate bin grid. Different elements have different colors; within each element are a number of separate rate bins corresponding to energy windows of width about 40%. Note: PHA data and bin alignment is not optimized in this figure; also SIT data will extend to higher f_e cells for heavy nuclei due to larger dynamic range on the solid state detector than in the Wind/STEP instrument.

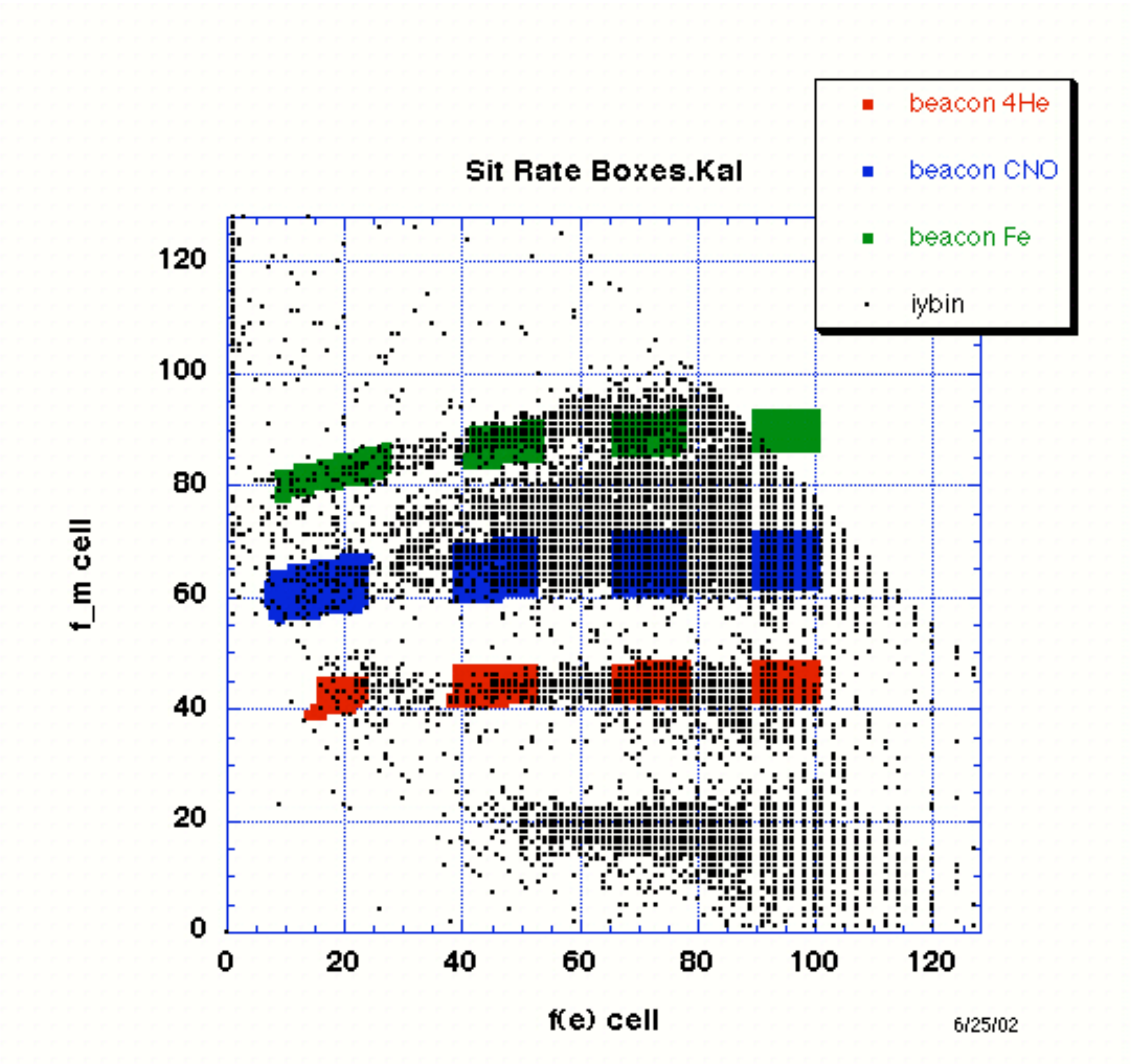


Figure 4. Same as fig. 3 except showing Beacon Rate bins (See Appendix 4). Note: PHA data and bin alignment is not optimized in this figure.

7.2 PHA events

Each Valid Event measured by SIT is formatted into a 32 bit long PHA event, whose contents are shown in Table 4. The Valid Event rate (same as the VSE rate) can be up to 1000 events/sec, and so, for a 60 s collection interval, up to 60,000 events can be measured. This number is much larger than the number of events that can be included in a science data record. Therefore, an event selection must be made to decide which events to telemeter.

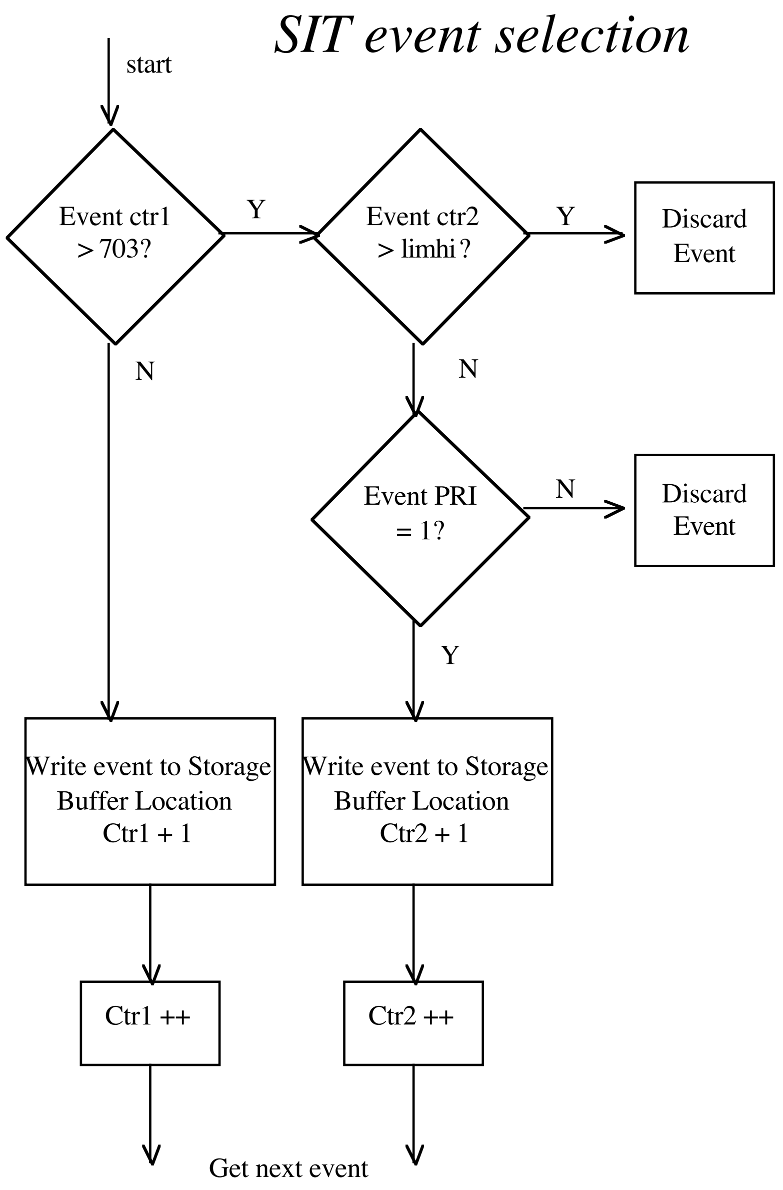
The selection of PHA event records is based in part upon the priority bit from the 128 x 128 Matrix Rate lookup table. The priority bit for each event is the high order bit (=128) of the first byte for each cell in the lookup table. There are two priorities, 0 and 1 (high).

Storage of PHA events in the buffer for readout is done as shown in figure 5. The storage buffer has room for 704 events, the number that can be telemetered in 60s. After the buffer has been cleared for a new 60s interval, the first 704 events are written into the buffer without regard to the priority bit. After that, high priority (=1) events only are written into the buffer, overwriting events that are already there. The high priority overwriting starts at the first event in the buffer, and continues up to a limit (= LIMHI) that is set by the command state of the instrument. Typically, LIMHI might be 500, so that about 70% of the events are high priority in cases where there are high intensities of high priority events.

At the end of the 60s collection interval, the storage buffer is transferred to a 2nd buffer for readout into telemetry packets (alternately, the storage and readout buffers could be interchanged). The buffer and counters are cleared and the process is repeated. Note that no time information is obtained for the individual events within the 60s period, and that if high priority events overwrite events at the start of the buffer, the buffer's events will not be in sequential time order. Since SIT is not able to obtain meaningful measurements on time intervals less than 60s, these features of the storage scheme do not affect the data analysis.

Table 4. PHA event record (see Appendix 5 for details)

Data type	Size (bits)
TOF channel	9
SSD channel	11
TOF FLG 0	1
TOF FLG 1	1
SSD gain bit (0 = high)	1
TOF error process	1
ROM box number	7
Priority	1
Total	32



SIT event selection

Notes:
Every 60 s:
xfr storage buffer to (2nd) readout buffer
Set ctr1 and ctr2 = 0
Zero out storage buffer

6/14/02

Figure 5. Block diagram of the PHA event storage.

8. Science data packets

At the end of the 60 second interval, the rate data is compressed (24→16 bits) and these compressed rates and PHA data are formed into packets. The SIT science data is allocated 12 each 272 byte packets per minute for telemetry. SIT produces packets in 2 formats (flight data): PHA packets (11/minute) and a RATE packet (1/minute) In addition to the PHA and rate data, the packets contain header information, checksums, and miscellaneous housekeeping information. The overall telemetry rate (w/o encoding) is approximately 12*272*8/60 = 435.2 bits/second. The primary content is listed in Table 5, and the detailed content and format of these packets is given in Appendices 7 and 8.

In addition to the PHA and RATE packets, there is other information (housekeeping and beacon rates) that is also transmitted. For testing with the instrument GSE, these constitute separate packet types, but inflight this data will be combined with that from other portions of the IMPACT instrument and will have a different format than shown in the Appendices.

Table 5. Packet contents

Packet type	**Size (bytes)**
PHA – 11 per 60 s interval 64 events per packet …+ checksum … +	11 x 272
RATE – 1 per 60 s interval 8 discriminator rates 116 Matrix Rates y … + checksum + … + housekeeping	1 x 272
Total	**3264 bytes/60 sec**

9. Off-line Computation of Intensities

For data analysis on the ground, particle intensities corresponding to individual Matrix Rate (MR) boxes are easily calculated since the MISC processor is fast enough to process all events entering the telescope. For a single readout of Matrix Rate j (=MR_j), the particle intensity, I_j. is given by

$$I_j = \frac{1}{T \times A\Omega \times \varepsilon \times \Delta E} MRj \tag{7}$$

where T is the collection time (60 s), $A\Omega$, is the geometry factor, ε is the efficiency for this species and energy, and ΔE is the energy interval covered by this MR box. Appendix 3 lists the Matrix Rate boxes, showing the species and energy intervals available.

In addition to intensities calculated using individual Matrix Rate boxes, particle intensities can be constructed with much greater energy and mass resolution (but also with smaller statistics) using the PHA event data. In this calculation, the Matrix Rate boxes are used to compute an overall normalization to take into account the effects of PHA sampling. Equation (8) gives the formula for calculating the particle intensity, I_j for a single 60 s interval corresponding to an arbitrary area of the *time vs. energy* matrix data from SIT (i.e. an area in the *t vs E* plane shown in Fig. 2). The coefficient is the same as equation (7), N_{0j} is the number of PHA events with priority 0 in this area in the matrix, and N_{1j} is the number of PHA events with priority 1 in this area in the matrix. N_o and N_1 are the number of PHA events of priority 0 and 1 in the entire matrix. Finally, MR1 and MR2 are the total number of counts of priority 0 and 1, respectively (see Appendix 3).

$$I_j = \frac{1}{T \times A\Omega \times \varepsilon \times \Delta E} \left(\frac{N_{0j} MR1}{N_0} + \frac{N_{1j} MR2}{N_1} \right) \tag{8}$$

Note that in many cases, an intensity calculated with equation (8) will correspond to an area of the PHA matrix that has only priority 0 or priority 1 events – in this case only one term in the parenthesis in equation (8) will contribute. If the selected area in the *t vs E* crosses a priority boundary then both terms must be used.

Both equations (7) and (8) give the formulas for calculating intensities from a single 60 second period, with the Matrix Rate rates from that period's rate packet, and the PHA summations taken from the PHA packets of the same period. Longer term averages are built up simply by averaging a succession of individual intensity calculations.

10. Command word

10.1 COMMANDS TO FRONT END LOGIC

The following commands are passed on to the front end logic:

10.1.1 One-Bit Commands - the following commands consist of a single bit each and control a single function in the front-end logic.

10.1.1.1 HV Enable - enables the high voltage power supply

1=enable, 0 = disable, turn-on state = 0,
Expected use: sent every time instrument is turned on to NORMAL (or Science) mode.

10.1.1.2 EONLY - allows analysis of events based on energy without the TOF

1 = EONLY, 0 = normal mode, turn-on state = 0
Expected use: diagnostic or in case of failure of TOF system

10.1.1.3 SPARE

10.1.2 Data Commands (8 bits) - the following command contains 8 bits of data and controls an analog function in the front-end electronics.

10.1.2.1 HV Level - sets the top voltage out of the HVPS

values: 0-255, 0 = 0 volts, 255 = tbd (~5000v), turn-on state = 0

Expected use: several commands will be sent each time the instrument is turned on into NORMAL (or Science) mode to step the HV up to the correct operating level. In addition, on rare occasions (perhaps once per year) the HV will need to be changed to compensate for operational loss of gain in the micro-channel plates.

10.1.2.2 SPARE

10.2 COMMANDS TO THE MISC

The following commands are processed within the MISC, setting flags or changing values in memory.

10.2.1 State Commands - the following commands set the MISC operating mod**e**

10.2.1.1 TOF Error Events: tells MISC whether to process events with TOF error bits set

1 = process events independent of TOF error bits
0 = only process events with TOF error flags = 0
turn-on state = 0

Expected usage: diagnostic and error recovery

10.2.1.2 Set LIMHI

For a single major frame, the first 704 PHA events are written into a buffer without regard for priority (64 events/packet x 11 packets/60 s = 704 events). If additional events are analyzed, and IF they have high priority, they are written into the PHA buffer starting at the beginning, overwriting prior events. The number of events that can be overwritten is set by the number LIMHI (see Fig. 5). The default value of LIMHI is 500, but any value may be set by command (10 bits).

Table 6. Command status (see PHA packet description for location)

Item	Size (bits)
HV step	8
enable TOF events w errors (process events with TOF error flags on)	1
enable HV	1
Analyze SSD only(VS=true)	1
ROM box 0 PHA events to be included in telemetry	1
LIMHI	10
lookup table checksum	12
Total	

10.2.1.3 Enable transmission of ROM box = 0 events

In the matrix lookup for PHA events, ROM box =0 is the returned value if the PHA event generates coordinates that fall outside the lookup table. These events are background, and so are normally discarded. If this bit is set, events with ROM box = 0 will be included in the transmitted PHA data.

10.2.2 Data Commands - the following commands change contents of MISC memory

10.2.2.1 Look-Up Tables -

We will need to be able to change the SIT event-processing look-up tables by command from the ground. Expected usage - probably a number of table uploads in the early weeks of instrument operation and then rare changes afterwards.

10.2.2.2 Program Memory -

We need to be able to patch SIT S/W by ground command. Expected usage - recovery from problems in instrument or mission.

The SIT command status information is summarized in Table 6. These data are read out in bytes 263-265 of the Rate Packet (see Appendix 7)

Table 6. Command status

Item	**Size (bits)**	**State at turn on**	**Read out byte in Rate Packet (APID 605)**
HV step	8	0	260
enable transmission of events with TOF error bit on (1=enable)	1	0	
enable HV (1=enable)	1	0	261
Analyze SSD only (1 = enable, 0 = require VS)	1	0	261
enable events with TOF error flags on (0 = not transmitted; = 1 transmit)	1	0	261
LIMHI	10	500	262-263
lookup table checksum	16	92 71 43 hex	264-266
Total			

Notes: LIMHI is the maximum slot number in the PHA storage buffer that is written over by Priority 1 events.

11. Housekeeping

Housekeeping analog data is periodically sampled and digitized by SIT and sent to the SEP DPU.

Table 7. Housekeeping data

Content	Size (bytes)
TOF gain * 2048	2
TOF cal / (-64)	2
TOF cal error	1
HV monitor	1
TOF temperature	1
foil temperature	1
3.3 V monitor	1
2.5 V monitor	1
5.0 V monitor	1
6.0 V monitor	1
software version	2
lookup table checksum	3
Total	

APPENDIX 1 -- SIT MATRIX RATE BIN CALCULATION:

1) Overview

The procedure calculates pseudo-mass (“amass”) and pseudo-energy/nucleon (“einc”) from the measured time-of-flight (“tof”) in ns, and total energy deposit in the solid state detector (“essd”) in MeV. For these quantities,

$$\text{amass} = \text{essd} * 0.021 * \text{tof}^{2} \tag{A1-1}$$

$$\text{einc} = 1 / (0.021 * \text{tof}^{2}) \tag{A1-2}$$

then, the values in the lookup matrix for pseudo-mass (f_m) and pseudo-energy/nucleon (f_e) are given by

$$\begin{aligned} \text{f\_m} &= (\text{alog}(\text{amass}) + 1) * (128/7) \\ &= (\text{alog}(\text{essd}) - \text{alog}(\text{einc}) + 1) * (128/7) \end{aligned} \tag{A1-3}$$

$$\text{f\_e} = (\text{alog}(\text{einc}) + 5.5) * 16 \tag{A1-4}$$

These expressions give values between 1 to 128 for particles of interest. For certain values of tof and energy, f_m and/or f_e will lie outside the allowed range, so the values require limit checking after the calculation.

2) MISC version of calculation

In order to carry out the calculation of f_e and f_m in the MISC, the above calculations need to be done as integers, and must further meet the condition that the 3-byte MISC words do not overflow in any part of the calculation—i.e. all intermediate terms must be less than 2^{24} (16,777,216).

The log functions needed for equations (A1-3) and (A1-4) are incorporated into lookup tables that have one entry for each SSD channel number (2048 entries; 2 gain states) and each tof channel number (512 entries), so no log calculations are required in the MISC processing: the calculation is carried out in integer arithmetic with using only simple add/subtract and multiply/divide.

In order to maintain numerical precision in the integer version of the lookup tables for the log of the SSD (MeV) and tof (ns) values, an offset is added to make all the values positive, and the resulting real number is multiplied by 2^{16}, and kept as an integer. In using equations (A1-3) and (A1-4), this scaling by 2^{16} is equivalent to multiplying both sides by 2^{16} to get:

$$\begin{aligned} 2^{16} * [\ \text{f\_m} &= (\text{alog}(\text{amass})) + 1) * (128/7)\ ] * 2^{16} \\ &= (\text{alog}(\text{essd}) - \text{alog}(\text{einc}) + 1) * (128/7)\ ] * 2^{16} \\ &= (2^{16}*\text{alog}(\text{essd}) - 2^{16}*\text{alog}(\text{einc}) + 2^{16}) * (128/7)\ ] \end{aligned} \tag{A1-3a}$$

$$2^{16} * [\ f\_e = (\mathrm{alog}(einc) + 5.5) * 16\ ] * 2^{16}$$
$$= (2^{16}*(\mathrm{alog}(einc)) + 2^{16}*(5.5)\ ) * 16 \qquad \text{(A1-4a)}$$

The lookup tables contain the following:

For the solid state detectors the high gain (gain bit = 0)cells contain the following entries for the energy (essd) corresponding to each channel number:

$$issdhi = (\mathrm{alog}(essd) + Khi)*2^{16} \qquad \text{(A1-5)}$$

and for low gain (gain bit = 1)

$$issdlo = (\mathrm{alog}(essd) + Klo)*2^{16} \qquad \text{(A1-6)}$$

For the time-of-flight analyzer each channel number of the time-of-flight has an entry in the table of:

$$itof = (\ \mathrm{alog}(0.021*tof^2) + Ktof)*2^{16}$$
$$= (\ -\ \mathrm{alog}(einc) + Ktof)*2^{16} \qquad \text{(A1-7)}$$

Where the Khi, Klo, and Ktof are the offsets required to make all the table entries positive. Substituting the issdlo or issdhi (=issd below) and itof values from (A1-5), (A1-6) and (A1-7) into equations (A1-3a) and (A1-4a) we have

$$2^{16} * [\ f\_m = (issd - K*2^{16} + itof - Ktof*2^{16} + 2^{16})*(128/7)\ ]$$

where the K stands for Klo or Khi depending on the gain bit of the SSD (0 or 1). So finally,

$$\boxed{f\_m = [(issd - K*2^{16} + itof - Ktof*2^{16} + 2^{16})*(128/7)\ ]/2^{16} \qquad \text{(A1-8)}}$$

For the f_e calculation, substituting equation (7) into equation (4a), we have

$$2^{16} * [\ f\_e = (\ -\ itof + Ktof*2^{16}) + (5.5)*2^{16}) * 16\ ]$$

So then,

$$\boxed{f\_e = [(\ -\ itof + Ktof*2^{16}) + (5.5)*2^{16}) * 16\ ]/2^{16} \qquad \text{(A1-9)}}$$

The MISC processor routine evaluates equations (A1-8) and (A1-9). The cell values, channel limits, and offsets are stored in the lookup tables as shown in Appendix2. The order of the calculation in the MISC, and certain intermediate values are combined (e.g. 1/4096 instead of 16/2^16 in equation A1-9) in order to avoid integer overflow or excess steps. *The divide by 7 in equation (A1-8) is implemented as (1/8 + 1/64) for quicker computation in the MISC processor (accurate to ~1.6%).*

APPENDIX 2 -- FLIGHT LOOKUP TABLES

TABLE A2-1 -- SSDHI INPUT FILE CONTENTS

<u>USED when PHA gain bit = 0</u>

Line number	Contents
1	high gain offset
2	low channel limit (>=6)
3	high channel limit (=<2048)
4	creation date: MMDDYY
5	version number
6	issdhi(6)
7	issdhi(7)
...	
...	
2048	issdhi(2048)

For channel N, let E = the energy output of the solid state detector in MeV,
Then,

$$issdhi(N) = (\ln(E) + 8) \times 2^{16} \qquad \text{(A2-1)}$$

Where:

high gain offset = second term of equation (A-1), i.e. 8 x 2^16 (an integer)

low channel limit and high channel limits are bounds checked before calculation of rate box

creation date format, e.g., 060502 (June 5, 2002)
version number: integer

Example: first several entries of the table ssdhi_hex_v01:

Line	HEX value	(Decimal value)
1	000000	0
2	000005	5
3	0007FE	2046
4	00EC56	60502
5	000001	1
6	036513	222484
7	041685	267910
8	047E52	294482
9	…etc	…etc

<u>Note: ONLY the HEX values are written out the file used by SIT simulator (fortran) pgm.</u>

TABLE A2-2 -- SSDLO INPUT FILE CONTENTS

<u>USED when PHA gain bit = 1</u>

Line number	Contents
1	low gain offset
2	low channel limit (>=6)
3	high channel limit (=<2048)
4	creation date: MMDDYY
5	version number
6	issdlo(6)
7	issdlo(7)
...	
...	
2048	issdlo(2048)

For channel N, let E = the energy output of the solid state detector in MeV,
Then,

$$issdlo(N) = (\ln(E) + 8) \times 2^{16} \qquad \text{(A2-2)}$$

Where:

low gain offset = second term of equation (A-2), i.e. 8 x 2^16 (integer)

low channel limit and high channel limits are
bounds checked before calculation of rate box

creation date format, e.g., 060502 (June 5, 2002)
version number: integer

Example: first several entries of the table ssdlo_hex_v01:

Line	HEX value	(Decimal value)
1	000000	0
2	000005	5
3	0007FE	2046
4	00EC56	60502
5	000001	1
6	057969	358762
7	062ADB	404188
8	0692A8	430761
9	…etc	…etc

<u>Note: ONLY the HEX values are written out the file used by SIT simulator (fortran) pgm.</u>

TABLE A2-3 -- TOF INPUT FILE CONTENTS

Line number	Contents
1	tof offset
2	low channel limit (>=6)
3	high channel limit (=<512)
4	creation date: MMDDYY
5	version number
6	tof(6)
7	tof(7)
...	
...	
512	tof(512)

For channel N, let *t* = the time of flight in nanoseconds (ns),
Then,

$$tof\,(N) = (\ln(0.21 * t * t) + 8) \times 2^{16} \qquad \text{(A2-3)}$$

Where:

tof offset = second term of equation (A-3), i.e. 8 x 2^16 (integer)
low channel limit and high channel limits are
bounds checked before calculation of rate box
creation date format, e.g., 060502 (June 5, 2002)
version number: integer

Example: first several entries of the table tof_hex_v01:

Line	HEX value	(Decimal value)
1	000000	0
2	000005	5
3	0001FF	511
4	00EC56	60502
5	000001	1
6	05820C	360973
7	05BEEB	376556
8	05F551	390482
9	…etc	…etc

Note: ONLY the HEX values are written out the file used by SIT simulator (fortran) pgm.

TABLE A2-4 -- RATE AND PRIORITY MATRIX

Corresponds to the 128 x 128 cell f_m vs. f_e matrix, but is stored as a file with 16384 lines, 1 item per line.

Line number	Contents
1	cell f_e = 1, f_m = 1
2	cell f_e = 1, f_m= 2
3	cell f_e = 1, f_m = 3
4	etc.
128	cell f_e = 1, f_m = 128
129	cell f_e = 2, f_m = 1
...	etc.
...	
16384	cell f_e = 128, f_m = 128

Contents of each 24-bit word:

byte 3 (high order)								byte 2								byte 1 (low order)							
23							16	15				11	10	9	8	7	6	5	4	3	2	1	0
												msb			lsb		msb						lsb
												B3	B2	B1	B0	P	M7	M6	M5	M4	M2	M1	M0

Where:

blank = not used (0)

B0-B4 = Beacon Box Number (actual current range 1-12)

P = Priority: = 0 (low) or 1 (high); where high priority is allowed to overwrite certain low priority events in the readout buffer

M0-M6 = Matrix rate: 1-128 (currently using 1-116 only)

Comment:
The most common cell contents correspond to “junk” (i.e. not corresponding to a matrix or Beacon Rate cell): 7 (low priority region) and 135 (87 Hex) (= 7 + 2^7) in hi priority region.

Example rate and priority lookup matrix cell values (version of 6/25/02):

Line No.	Cell contents	Items in cell		
		Priority	Beacon rate #	Matrix rate #
1	7	0	0	7 (junk)
2	7	0	0	7
3	7	0	0	7
4	7	0	0	7
5	7	0	0	7
6	7	0	0	7
7	7	0	0	7
…	…			
127	87	1	0	7
128	87	1	0	7
129	7	0	0	7
130	7	0	0	7
131	7	0	0	7
…	…			7
2854	7	0	0	7
2855	7	0	0	7
2856	18	0	0	24
2857	18	0	0	24
2858	117	0	1	23
2859	117	0	1	23
2860	117	0	1	23
2861	117	0	1	23
2862	7	0	0	7
…	…			
5454	000CD	1	0	77
5455	000CD	1	0	77
5456	000CD	1	0	77
5457	87	1	0	7
5458	87	1	0	7
5459	87	1	0	7
5460	00ADE	1	10	94
5461	00ADE	1	10	94
5462	00ADE	1	10	94
5463	00ADE	1	10	94
5464	00ADE	1	10	94
…	…			
16381	87	1	0	7
16382	87	1	0	7
16383	87	1	0	7
16384	87	1	0	7

APPENDIX 3 -- SIT MATRIX RATE ASSIGNMENTS

The table lists the logical contents of each box.

Notes:
1) Pri 0 = sum of all counts with priority 0
2) Pri 1 = sum of all counts with priority 1
3) Hi ramp = count rate of particles in high gain (gain bit = 0) range
4) Lo ramp = count rate of particles in low gain (gain bit = 1) range
5) discarded = sum of counts discarded due to FIFO full + counts left in FIFO at end of 60s processing period (when interrupt occurs)
6) 'out bnds' = events whose SSD or tof channel number is outside the low or high channel limits; OR whose computed f_e or f_m value is out side the limits of the input array (1-128 for both variables)
7) Junk = sum of all counts with 'junk' box (#7)

Note: consistency check if all rate counts are 4095 or less:

$$Box1 + Box2 = Box3 + Box4 = \sum_{i=7}^{116} Box_i$$

If rate counts in any box exceed 4095, then due to loss of precision in prescaling, the above relationships in general will not be met exactly.

TABLE A3-1 – Matrix rate assignments

Matrix Rate Box No.	title or element	Emin	Emax	Mass min	Mass max	Mass avg	Z
1	'Pri 0'	0	0	0	0	0	0
2	'Pri 1'	0	0	0	0	0	0
3	'Hi ramp'	0	0	0	0	0	0
4	'Lo ramp'	0	0	0	0	0	0
5	'discarded'	0	0	0	0	0	0
6	'out bnds'	0	0	0	0	0	0
7	'Junk'	0	0	0	0	0	0
8	'H'	0.0800	0.1131	0.5	1.5	1	1
9	'H'	0.1131	0.1600	0.5	1.5	1	1
10	'H'	0.1600	0.2263	0.5	1.5	1	1
11	'H'	0.2263	0.3200	0.5	1.5	1	1
12	'H'	0.3200	0.4525	0.5	1.5	1	1

13	'H'	0.4525	0.6400	0.5	1.5	1	1
14	'H'	0.6400	0.9051	0.5	1.5	1	1
15	'H'	0.9051	1.2800	0.5	1.5	1	1
16	'H'	1.2800	1.8102	0.5	1.5	1	1
17	'H'	1.8102	2.5600	0.5	1.5	1	1
18	'H'	2.5600	3.6204	0.5	1.5	1	1
19	'H'	3.6204	5.1200	0.5	1.5	1	1
20	'H'	5.1200	7.2408	0.5	1.5	1	1
21	'3He'	0.1500	0.2500	2.5	3.2	3	2
22	'3He'	0.8000	1.2000	2.5	3.2	3	2
23	'4He'	0.0283	0.0400	3.5	5.0	4	2
24	'4He'	0.0400	0.0566	3.5	5.0	4	2
25	'4He'	0.0566	0.0800	3.5	5.0	4	2
26	'4He'	0.0800	0.1132	3.5	5.0	4	2
27	'4He'	0.1132	0.1601	3.5	5.0	4	2
28	'4He'	0.1601	0.2264	3.5	5.0	4	2
29	'4He'	0.2264	0.3202	3.5	5.0	4	2
30	'4He'	0.3202	0.4528	3.5	5.0	4	2
31	'4He'	0.4528	0.6404	3.5	5.0	4	2
32	'4He'	0.6404	0.9056	3.5	5.0	4	2
33	'4He'	0.9056	1.2807	3.5	5.0	4	2
34	'4He'	1.2807	1.8112	3.5	5.0	4	2
35	'4He'	1.8112	2.5614	3.5	5.0	4	2
36	'4He'	2.5614	3.6224	3.5	5.0	4	2
37	'4He'	3.6224	5.1228	3.5	5.0	4	2
38	'4He'	5.1228	7.2448	3.5	5.0	4	2
39	'C'	0.0200	0.0283	10	13	12	6
40	'C'	0.0283	0.0400	10	13	12	6
41	'C'	0.0400	0.0566	10	13	12	6
42	'C'	0.0566	0.0800	10	13	12	6
43	'C'	0.0800	0.1131	10	13	12	6
44	'C'	0.1131	0.1600	10	13	12	6
45	'C'	0.1600	0.2263	10	13	12	6
46	'C'	0.2263	0.3200	10	13	12	6
47	'C'	0.3200	0.4525	10	13	12	6
48	'C'	0.4525	0.6400	10	13	12	6
49	'C'	0.6400	0.9051	10	13	12	6
50	'C'	0.9051	1.2800	10	13	12	6
51	'C'	1.2800	1.8102	10	13	12	6
52	'C'	1.8102	2.5600	10	13	12	6
53	'C'	2.5600	3.6204	10	13	12	6
54	'C'	3.6204	5.1200	10	13	12	6
55	'C'	5.1200	7.2408	10	13	12	6

56	'O'	0.0200	0.0283	15	17	16	8
57	'O'	0.0283	0.0400	15	17	16	8
58	'O'	0.0400	0.0566	15	17	16	8
59	'O'	0.0566	0.0800	15	17	16	8
60	'O'	0.0800	0.1131	15	17	16	8
61	'O'	0.1131	0.1600	15	17	16	8
62	'O'	0.1600	0.2263	15	17	16	8
63	'O'	0.2263	0.3200	15	17	16	8
64	'O'	0.3200	0.4525	15	17	16	8
65	'O'	0.4525	0.6400	15	17	16	8
66	'O'	0.6400	0.9051	15	17	16	8
67	'O'	0.9051	1.2800	15	17	16	8
68	'O'	1.2800	1.8102	15	17	16	8
69	'O'	1.8102	2.5600	15	17	16	8
70	'O'	2.5600	3.6204	15	17	16	8
71	'O'	3.6204	5.1200	15	17	16	8
72	'O'	5.1200	7.2408	15	17	16	8
73	'NeS'	0.0200	0.0283	19	34	24	12
74	'NeS'	0.0283	0.0400	19	34	24	12
75	'NeS'	0.0400	0.0566	19	34	24	12
76	'NeS'	0.0566	0.0800	19	34	24	12
77	'NeS'	0.0800	0.1131	19	34	24	12
78	'NeS'	0.1131	0.1600	19	34	24	12
79	'NeS'	0.1600	0.2263	19	34	24	12
80	'NeS'	0.2263	0.3200	19	34	24	12
81	'NeS'	0.3200	0.4525	19	34	24	12
82	'NeS'	0.4525	0.6400	19	34	24	12
83	'NeS'	0.6400	0.9051	19	34	24	12
84	'NeS'	0.9051	1.2800	19	34	24	12
85	'NeS'	1.2800	1.8102	19	34	24	12
86	'NeS'	1.8102	2.5600	19	34	24	12
87	'NeS'	2.5600	3.6204	19	34	24	12
88	'NeS'	3.6204	5.1200	19	34	24	12
89	'NeS'	5.1200	7.2408	19	34	24	12
90	'Fe'	0.0200	0.0283	40	60	56	26
91	'Fe'	0.0283	0.0400	40	60	56	26
92	'Fe'	0.0400	0.0566	40	60	56	26
93	'Fe'	0.0566	0.0800	40	60	56	26
94	'Fe'	0.0800	0.1131	40	60	56	26
95	'Fe'	0.1131	0.1600	40	60	56	26
96	'Fe'	0.1600	0.2263	40	60	56	26
97	'Fe'	0.2263	0.3200	40	60	56	26
98	'Fe'	0.3200	0.4525	40	60	56	26

99	'Fe'	0.4525	0.6400	40	60	56	26
100	'Fe'	0.6400	0.9051	40	60	56	26
101	'Fe'	0.9051	1.2800	40	60	56	26
102	'Fe'	1.2800	1.8102	40	60	56	26
103	'Fe'	1.8102	2.5600	40	60	56	26
104	'UH'	0.02	0.0400	80	240	132	54
105	'UH'	0.04	0.0800	80	240	132	54
106	'UH'	0.08	0.1600	80	240	132	54
107	'UH'	0.16	0.3200	80	240	132	54
108	'UH'	0.32	0.6400	80	240	132	54
109	'UH'	0.64	1.2800	80	240	132	54
110	'spare 1'	0	0	0	0	0	0
111	'spare 2'	0	0	0	0	0	0
112	'spare 3'	0	0	0	0	0	0
113	'spare 4'	0	0	0	0	0	0
114	'spare 5'	0	0	0	0	0	0
115	'spare 6'	0	0	0	0	0	0
116	'spare 7'	0	0	0	0	0	0

APPENDIX 4 -- BEACON MATRIX RATE ASSIGNMENTS

Beacon box number per Dick Mewaldt memo/spreadsheet dated 12/8/01

TABLE A4-1 Beacon rate boxes

Beacon Rate Box No.	title or element	Emin	Emax	Eff, ε (typ)	Mass min	Mass max	Mass avg	Z
1	'4He'	0.0283	0.0400	0.1	3.5	5.0	4	2
2	'4He'	0.0800	0.1600	0.22	3.5	5.0	4	2
3	'4He'	0.3200	0.6400	0.23	3.5	5.0	4	2
4	'4He'	1.2800	2.5600	0.1	3.5	5.0	4	2
5	'CNO'	0.0200	0.0400	1.	10	17	14	8
6	'CNO'	0.0800	0.1600	1.	10	17	14	8
7	'CNO'	0.3200	0.6400	1.	10	17	14	8
8	'CNO'	1.2800	2.5600	1.	10	17	14	8
9	'Fe'	0.0200	0.0400	1.	40	60	56	26
10	'Fe'	0.0800	0.1600	1.	40	60	56	26
11	'Fe'	0.3200	0.6400	1.	40	60	56	26
12	'Fe'	1.2800	2.5600	1.	40	60	56	26

Algorithm:

$$Intensity = \frac{counts/s}{(E_{\max} - E_{\min})A\Omega * \varepsilon}$$

where AΩ = geometry factor; ε = efficiency (function of species & energy). Efficiency values (based on Wind/STEP postlaunch values) are given in the table.

AΩ = 0.30 cm^2-sr

Notes:
The regular Matrix Rate box numbers are telemetered in the PHA events, making it possible to verify the algorithm for calculating the box number, and comparing it with the flight data. There is no such check available on the Beacon Rates. However, an approximate or even an exact check on the Beacon Rates is possible by comparing Beacon Rate box counts with regular Matrix Rate counts. If the Beacon Rate mass and energy boundaries are exactly the same as the regular Matrix Rates, then an exact check is possible.

For example, for the Matrix Rates in Appendix 3 and the Beacon rates in the above table, the mass and energy boundaries coincide, allowing an exact check. On the next page the correspondence is given.

TABLE A4-2 Correspondence between Beacon & Matrix Rates

Correspondence between Beacon Rates and Matrix Rate boxes

Beacon rate number	Matrix rate numbers
1	23
2	26 + 27
3	30 + 31
4	34 + 35
5	39 + 40 + 56 +57
6	43 + 44 + 60 + 61
7	47 + 48 + 64 + 65
8	51 + 52 + 68 + 69
9	90 + 91
10	94 + 95
11	98 + 99
12	102 + 103

Note: If the number of counts in any box exceeds 4095, then due to loss of precision in the rate compression algorithm, the above equalities will not generally hold precisely.

If a different set of Matrix Rate or Beacon Rate boxes were chosen, the above table would of course change. As given, the sum of the indicated Matrix Rates will be exactly the same as the corresponding Beacon Rate.

APPENDIX 5 -- PHA EVENT CONTENTS

This table lists the 32 bit contents of each event which is put into the PHA packets.

Table A5-1 -- PHA event contents

Bit	Source	Name	Contents / comments
31 msb	L	Pri	Priority bit (0=low, 1=high)
30	L	Matrix box bit 6	MSB
29	L	Matrix box bit 5	
28	L	Matrix box bit 4	
27	L	Matrix box bit 3	
26	L	Matrix box bit 2	
25	L	Matrix box bit 1	
24	L	Matrix box bit 0	LSB
23	C	TOF ERROR PROC	command state bit
22	F	GAIN	SSD energy gain bit (0=high; 1=low)
21	F	TOF FLG 1	TOF error flag 1
20	F	TOF FLG 2	TOF error flag 0
19	F	E 10	MSB
18	F	E 9	
17	F	E 8	
16	F	E 7	
15	F	E 6	
14	F	E 5	
13	F	E 4	
12	F	E 3	
11	F	E 2	
10	F	E 1	
9	F	E 0	LSB
8	F	TOF 8	MSB
7	F	TOF 7	
6	F	TOF 6	
5	F	TOF 5	
4	F	TOF 4	
3	F	TOF 3	
2	F	TOF 2	
1	F	TOF 1	
0 lsb	F	TOF 0	LSB

Source abbreviations:
L = Matrix rate lookup table (low order byte)
C = command state bit
F = received from front-end logic/ACTEL

APPENDIX 6 -- SIT APID ASSIGNMENTS

This table gives the SIT APID packet descriptions. The APID is in the CCSDS header in the first 11 bytes of each packet (see Appendix 13).

note: the SIT GSE vs SEP Central put the housekeeping and beacon rates in different packets that have different formats (see Appendices 10 and 11 for formats)

Table A6-1 -- APID assignments

APID	APID (hex)	Packet Description
577	241	housekeeping (from SEP Central)
605	25D	RATE packet
606	25E	PHA packet #1
607	25F	PHA packet #2
608	260	PHA packet #3
609	261	PHA packet #4
610	262	PHA packet #5
611	263	PHA packet #6
612	264	PHA packet #7
613	265	PHA packet #8
614	266	PHA packet #9
615	267	PHA packet #10
616	268	PHA packet #11
617	269	test mode 2
618	26A	housekeeping (from SIT GSE)
619	26B	beacon rates (from SIT GSE)
623	26F	(empty packet from GSE)
624	270	beacon rates (from SEP Central)

APPENDIX 7 -- RATE PACKET CONTENTS - APID 605

The rate packet contains discriminator and matrix rates, and command status information. There is no multiplexing.

Table A7-1 -- RATE packet contents

Byte #	Description	UMd GSE to Winmac hex Byte #
1-11	CCSDS header	--
12-13	Discriminator Rate (=DR) 1-- START singles	1-2
14-15	DR2 – STOP singles	3-4
16-17	DR3 – Valid Stop	
18-19	DR4 – SSD singles	
20-21	DR5 – Event (triple coincidence)	
22-23	DR6 – Dead time counter	
24-25	DR7 – Artificial STOP count (TOF diagnostic)	
26-27	DR8 – TOF system error count	
28-29	Matrix Rate (=MR) 1 --	
30-31	MR2	
32-33	MR3	
34-35	MR4	
36-37	MR5	
...	...	
258-259	MR116	
260	hvstep	
261	4 1-bit flags: bit 0 (lsb): 0 = TOF error events transmitted 0 = TOF error events dropped bit 1: 0 = HV disabled 1 = HV enabled bit 2: 0 = VS required for analysis 1 = SSD only required for analysis bit 3: 0 = ROM box 0 events dropped 1 = ROM box 0 events transmitted	
262-263	LIMHI	
264-266	3-byte lookup table checksum	253
267-271	spare	
272	checksum	261

APPENDIX 8 -- PHA PACKET CONTENTS - APIDs 606-616

Table A8-1 -- PHA packet contents

Byte #	Description	UMd GSE to Winmac hex Byte #
1-11	CCSDS header	--
12-15	PHA event 1	3-6
16-19	PHA event 2	7-10
20-23	PHA event 3	
24-27	PHA event 4	
...	...	
264-267	PHA event 64	
268	spare	259
269	spare	260
270	spare	261
271	Number of PHA events in packet	262
272	checksum	263

APPENDIX 9 -- TEST MODE 2 PACKET CONTENTS - APID 617

NOTE: THIS FORMAT IS FOR USE WITH THE GSE ONLY: THERE IS NO APID 617 FOR FLIGHT DATA

Table A9-1 -- Test Mode 2 packet

Byte #	Description	UMd GSE to Winmac hex Byte #
1-11	CCSDS header	
12-272	currently unimplemented	
272	checksum	

APPENDIX 10 -- HK PACKET CONTENTS - APID 577 & 618 (gse)

NOTE: When SIT is running through SEP CENTRAL, the HK comes out in APID 577; when running with its own GSE it comes out in APID 618. In APID 577, other bytes are assigned to other sensors.

Table A10-1 -- HK (housekeeping) packet

APID 577 Byte #	APID 618 Byte #	Description	UMd GSE to Winmac hex Byte #
1-11	1-11	CCSDS header	--
181-182	12-13	Major Frame number	1-2
183-184	14-15	TOF gain Cal * 2048	3-4
185-186	16-17	TOF Cal offset * -64	5-6
187	18	TOF Cal error	7
188	19	HV monitor	8
189	20	TOF temp (T1)	9
190	21	foil temp (T2)	10
191	22	SSD temp (T3)	11
192	23	+3.3 V monitor	12
193	24	+2.4 V monitor	13
194	25	+5.0 Digital V monitor	14
195	26	+6.0 V monitor	15
196-197	27-28	Software version	16-17
198-200	29-31	lookup table checksum	18-20
	32-271	unused	
272	272	checksum	

APPENDIX 11 -- BEACON RATE PACKET CONTENTS - APID 624 & 619 (gse)

NOTE: Beacon rates come out in APID 624 when data is from SEP CENTRAL; they are in APID 619 when coming from the SIT GSE.

Table A11-1 -- Beacon Rate packet contents

APID 624 Byte #	APID 619 Byte #	Description	UMd GSE to Winmac hex Byte #
1-11	1-11	CCSDS header	
155-156	12-13	Beacon rate 1 (compressed)	1-2
157-158	14-15	Beacon rate 2 (compressed)	3-4
159-160	16-17	3	
161-162	18-19	4	
163-164	20-21	5	
165-166	22-23	6	
167-168	24-25	7	
169-170	26-27	8	
171-172	28-29	9	
173-174	30-31	10	
175-176	32-33	11	
177-178	33-34	Beacon rate 12 (compressed)	
	35-271	unused	
272	272	checksum	

APPENDIX 12 -- GSE EMPTY PACKET CONTENTS - APID 623

NOTE: THIS PACKET TYPE APPEARS IN THE GSE DATA ONLY AND WILL NOT APPEAR IN FLIGHT

Table A12-1 -- GSE Empty Packets

Byte #	Description
1-11	CCSDS header
12-272	0

This packet is put out by the GSE and will not be in the flight data.

APPENDIX 13 -- CCSDS HEADER

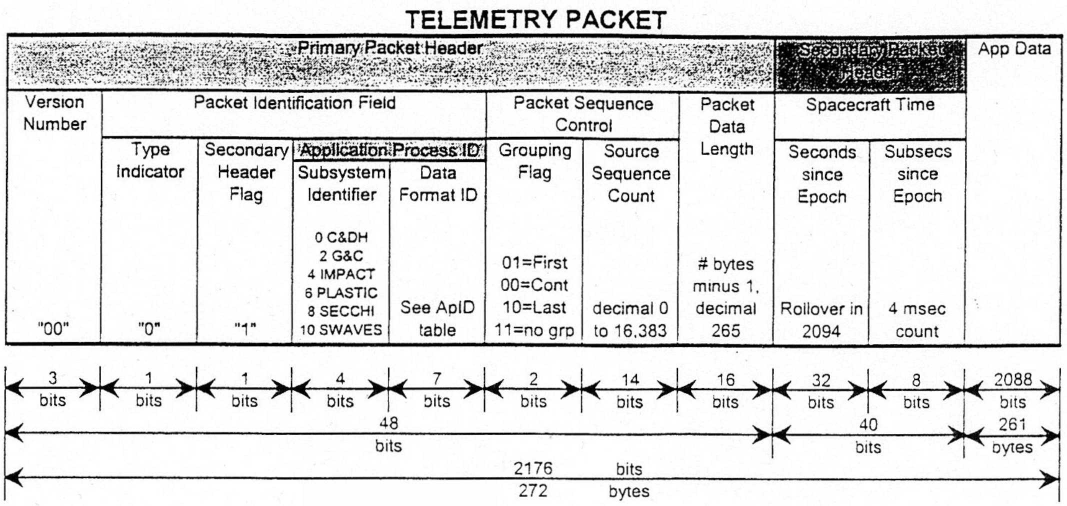


Figure 13. CCSDS Telemetry Packet Data Structure Diagram

For the first two bytes of the 11-byte header:

byte 1 (low order byte)								byte 2							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
msb															lsb
									A7	A6	A5	A4	A3	A2	A1
0	0	0	0	1	0	1	0	0							

APID = bits 0 - 10 above; result is byte 2 + 2*256

TIME CONVERSION:

The Spacecraft time in seconds (bytes 7-10 of the header record) is seconds since Jan. 1, 1958.
To convert this to SAMPEX time (seconds since 1/1/1992), subtract:
1072915200
seconds (see excel spreadsheet: epoch to SAMPEX time calc.xls)

Example: Epoch time of: 58 06 99 cf (hex)
corresponds to 1476827599 sec., or a SAMPEX time of 403912399, and
real time of 2004-10-18 21:53:19

APPENDIX 14 -- RATE DECOMPRESSION ALGORITHM

Each 2 byte compressed rate is decoded as follows:

Table A-14-1 Compressed Rate Bit Assignments

byte 2								byte 1 (low order byte)							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
msb															lsb
E5	E4	E3	E2	E1	M11	M10	M9	M8	M7	M6	M5	M4	M3	M2	M1

ref: e-mail from Haydar, 7/15/04:

For each rate,

mantissa is given by M1-M11

exponent is given by E1-E5

then the decompressed value for COUNTS is given by

IF: exponent is less than or equal to 1, then COUNTS = mantissa

IF: exponent is greater than 1, then COUNTS = (mantissa + 2048)*2^exponent

APPENDIX 15 -- ANALOG HOUSEKEEPING CALIBRATION

The conversion from channel number Ichan to analog value A for each housekeeping item is given by:

$$A = a_0 + Ichan \times a1$$

where:

Table A-15-1 Analog Housekeeping Calibration

		fm1		fm2	
Mux no.	Name	a0	a1	a0	a1
0	HV	4133.5260	-16.5870	4133.5260	-16.5870
1	DTOF temp	74.2278	-0.5190	75.8145	-0.5582
2	Foil temp	71.3783	-0.5134	77.4321	-0.5450
3	SSD temp	77.0773	-0.5245	82.1969	-0.5714
4	+3.3V	5.1000	-0.0200	5.1000	-0.0200
5	+2.5V	5.1000	-0.0200	5.1000	-0.0200
6	+5Dig V	10.2000	-0.0400	10.2000	-0.0400
7	+6V	10.1911	-0.0412	10.1911	-0.0412
		Vref	Vslope	Vref	Vslope
--	6V temp correction	6.1100	34.8300	6.1600	34.8300

ref: P Walpole e-mail 8/20/04; + fits to SIT fm1 HV cal 3/2/04, logbook #6, p 118
8/20/04 cal is nominal 1.0kV per 1.0V on control voltage; 3/2/04 cal was with mushroom, and showed actual voltage below nominal; see Mason stereo notebook #2 entries from 9/1/04 for derivation of HV coefficients in table A-15-1;
NOTE: this calibration is used for both fm1 and fm2 units

NOTE: for use with SEP CENTRAL, these calibrations will change due to difference in regulation accuracy of one of the reference voltages. To find the corrected temperature, calculate the 6V line value using above fit, also find nominal temps using above fits, THEN

$$T = T_{uncorr} - (Vref - 6V) \times Vslope$$

Note that the ±1 channel jitter on the +6V mux will cause a ~±1.43° jitter in the corrected temp.

APPENDIX 16 -- CHECKSUM CALCULATIONS

reference: Tom Nolan e-mail 8/19/04

1) PACKET CHECKSUM

The packet checksum (byte 272 of all packets) is set to a value N such that the sum S of all 172 bytes in the packet, including the checksum byte, is zero mod 256, i.e. mod(S,256) = 0. This checksum is calculated in the GSE program, and is also recomputed in SEP central when the CCSDS header is added, so it should always be right.

2) LOOKUP Table CHECKSUM

The lookup table checksum is the 24-bit sum of all the words in the table area. It should match the checksum calculated by the table size routine that appended the tables to the source files. This treats bits unequally, for example two bit flips from 0 to 1 in the lsb will be detected but in the msb will not.

For the ETU set of tables the files and values are:

File	table sum (decimal)
SSDHI_HEX_V01.TXT	1342073010
SSDLO_HEX_V01.TXT	1620489546
TOF_HEX_V01.TXT	398620253
SIT_RATE_BOX_VECTOR.HEX	3857642
sum of tables:	3365040451
low order 24 bits of checksum:	9597251
low order 24 bits of checksum (hex):	927143 (this is the telemetered number)

(program
$USER:[MASON.STEREO.PROC_MISC.FLIGHT_SIM]TABLE_CHECKSUM.FOR
is used to add up the tables).