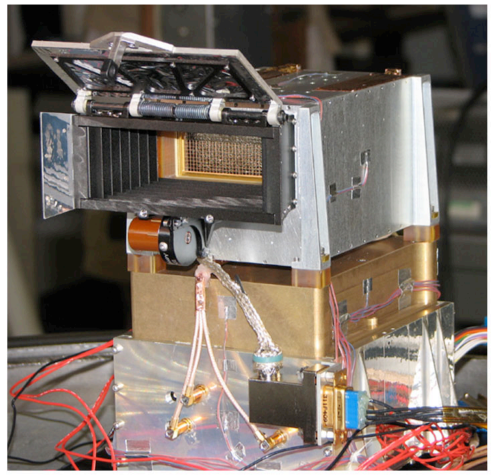
Description of the STEREO / IMPACT / SEP / Suprathermal-Ion-Telescope (SIT)



SIT - Suprathermal 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 8 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; June 23, 2006 ff	1) adjust HK algorithms, Appendix 17 2) add UMd GSE Winmac hex file byte assignments in packet description tables

Version	Date	Changes
2.6	Sept. 2005	Show fm1 flight lookup tables; update figures with tables; update rate table; add table for checksum values; add appendix 18
2.7	March 28, 2006	Limit decompressed rates to <2^24 (see appendix 16) Add Appendix 18 (operating temp limits table) 1/9/06; modify HK limits 2/7/06 Fix error in Table 6 on turn on value of TOFERROR bit Fix lower channel limit test in Appendix 2 tables (< instead of =<)
2.8	June 9, 2006	Update section 8 (data packets) and table 5 Change TOFERR status at turn on (to 0) Update to reflect 4/28/06 versions of lookup tables & checksums
2/9	March 16, 2007	Add Appendix 15 (GR Header) Add Appendix 7 for APID 576 (Cmd response); renumber & rearrange some of the appendices Update checksum table to show 3/14/07 new table upload values

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 for the Suprathermal-Ion-Telescope, and in particular describes the data and on-board processing. The SIT sensor is nearly identical to the Supra-Thermal-through-Energetic-Particle (STEP) sensors, on board the WIND spacecraft (von Rosenvinge *et al.*, *Space. Sci. Rev.*, 71, 155, 1995); however, the electronics and on-board data processing design were redone for SIT to make full use of the capabilities of the STEREO mission.

We wish to acknowledge the many individuals who contributed to the development of the SIT hardware and flight software, in particular: UMd: Joe Dwyer (matrix binning); at GSFC: Sandy Shuman, 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.

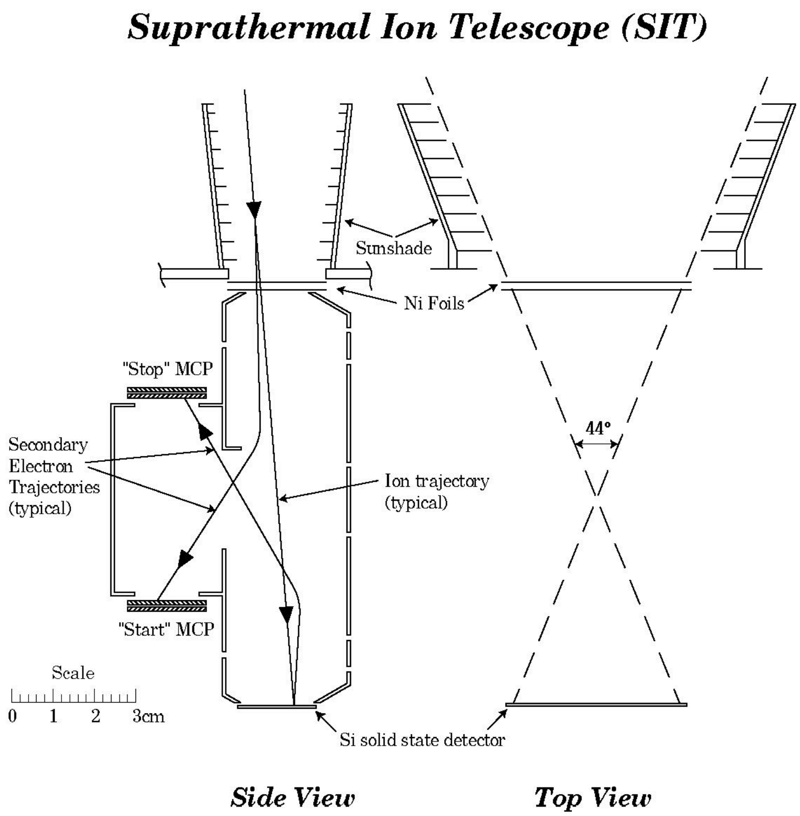

Figure 1. Schematic diagram of the sensor for the Suprathermal-Ion-Telescope (SIT).

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 10 cm 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.

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.

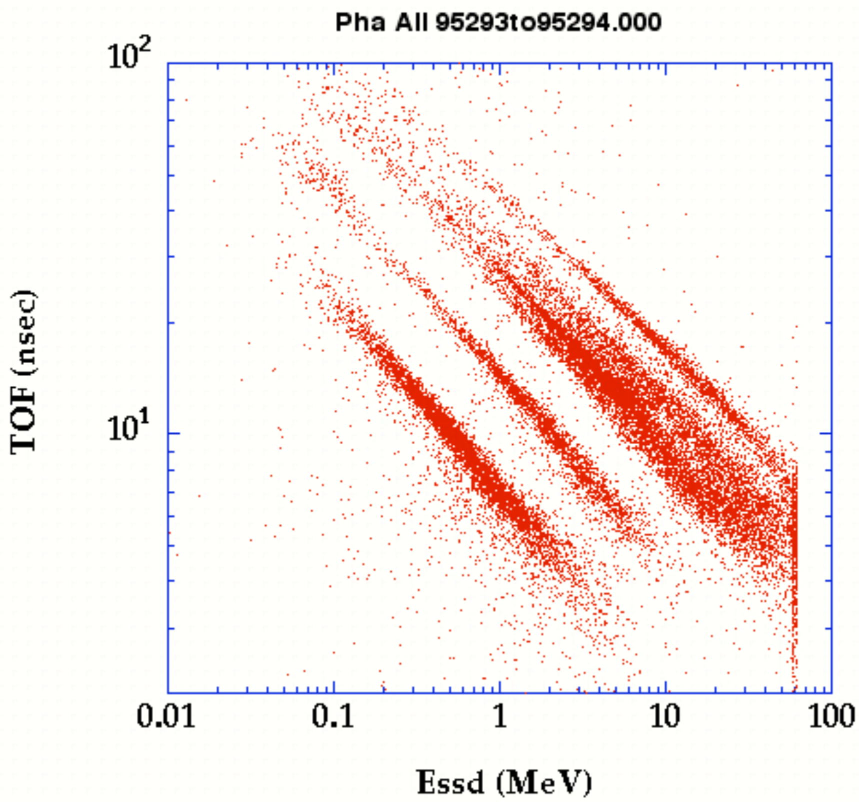

Figure 2. TOF versus the total kinetic energy for solar energetic particles, measured during the October 1995 event. The pulse height analysis (PHA) data are from the WIND/STEP sensors. The SIT Essd values will extend up to about 160 MeV, considerably higher than in this figure.

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 0.20 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 8).

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. Joe Dwyer proposed this approach to binning while at UMd. For these quantities, we have the following approximate expressions:

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

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

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

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

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

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 table names and used are listed in Table 3; additional details of the calculation are given in Appendix 1.

Figure 4 shows how BNL calibration 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 5 shows the same PHA data with Beacon Rate bins) 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	Name	Number of elements	Length (bytes)	Purpose
1	SSDHI	2048	3	SSD ramp 0 channel → log(E)
2	SSDLO	2048	3	SSD ramp 1 channel → log(E)
3	TOF	512	3	TOF Channel → log(M/E)+constant
4	BOX ARRAY	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)		

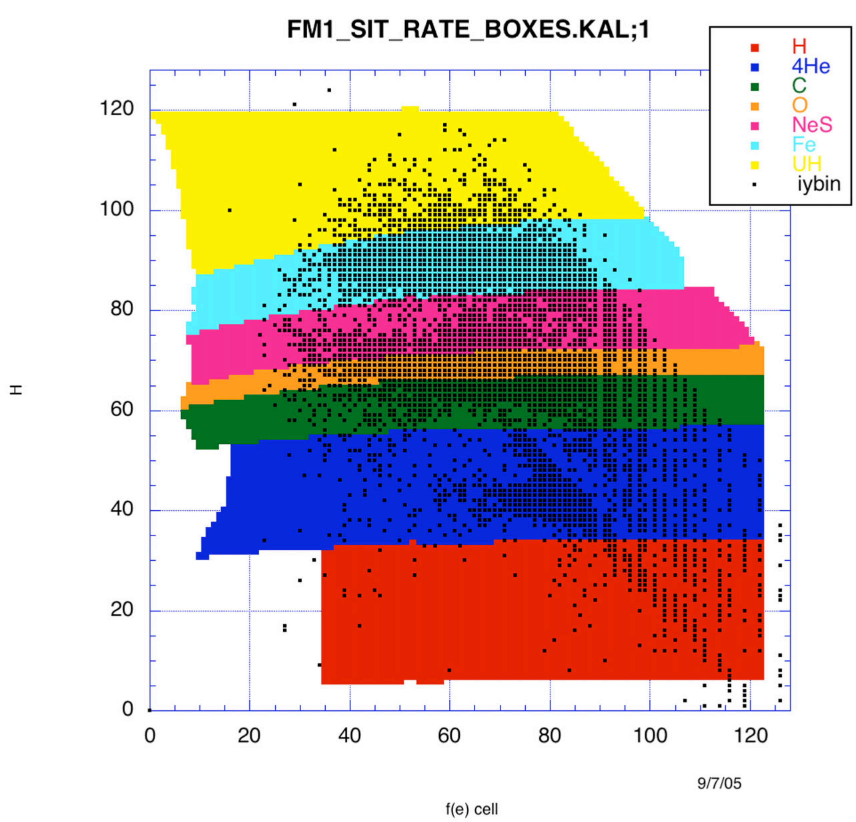

Figure 3. Valid Events (black dots from fm1 BNL calibration, August 2004) superposed on fm1 rate bin grid (v. 090105). Different

elements have different colors; within each element are a number of separate rate bins corresponding to energy windows of width about 40%. Note: horizontal features in PHA events are due to peaks in energy in the BNL data.

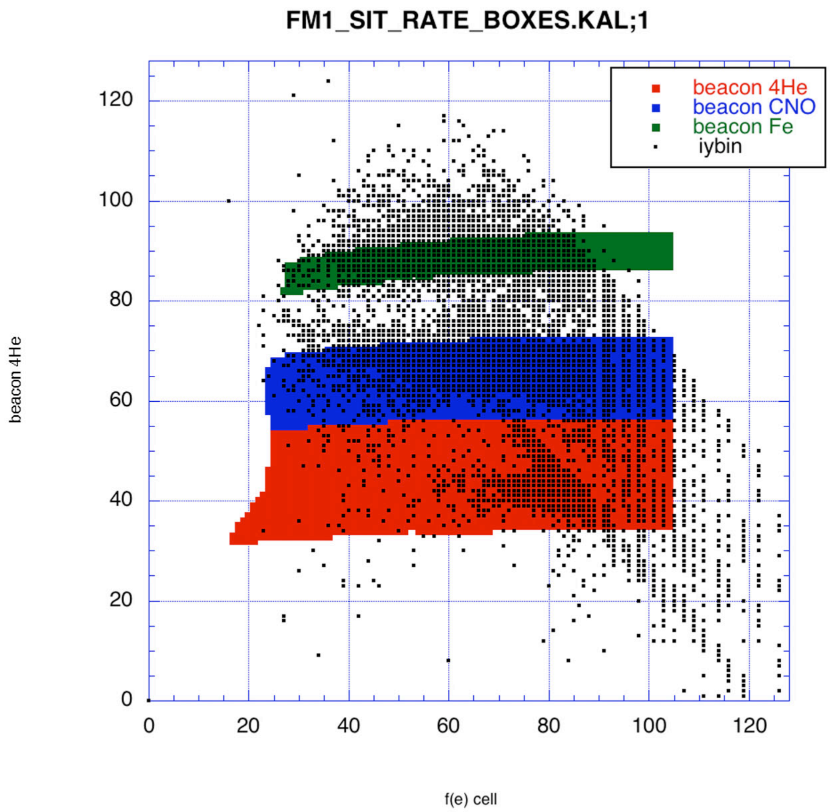

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Figure 4. Same as fig. 3 except showing Beacon Rate bins (See Appendix 4).

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). Figure 5 shows the assignment of priority for SIT fm1 tables (090105 version). In this case, high priority was assigned to all regions of the matrix corresponding to rates with $Z \geq 6$. In the initial flight set of tables, the high priority corresponds to all rates C through Fe, but not UH.

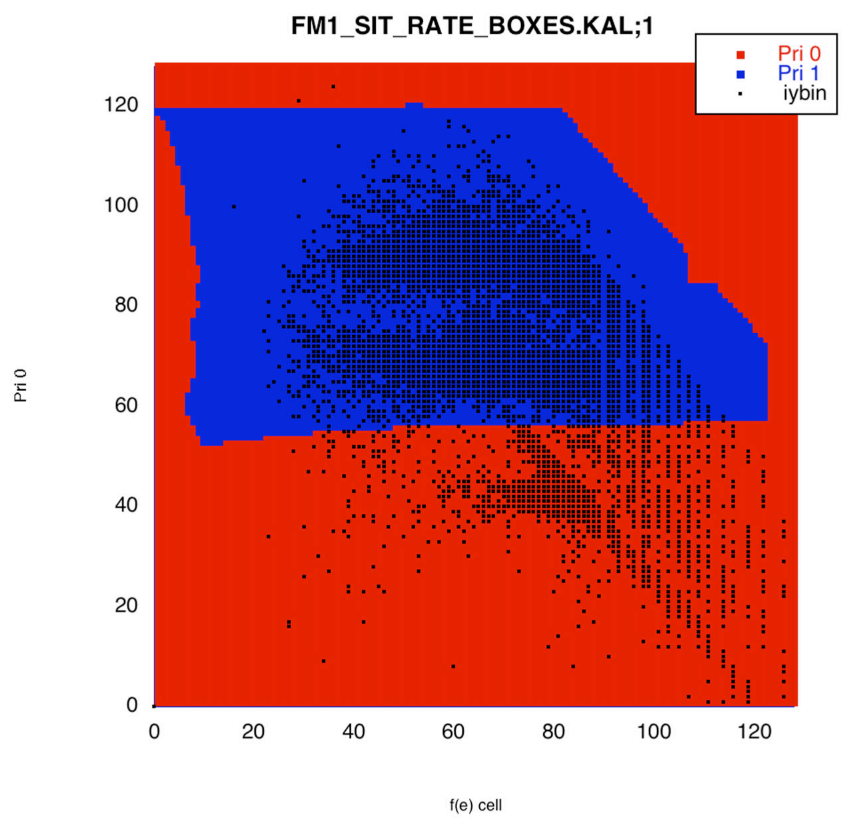


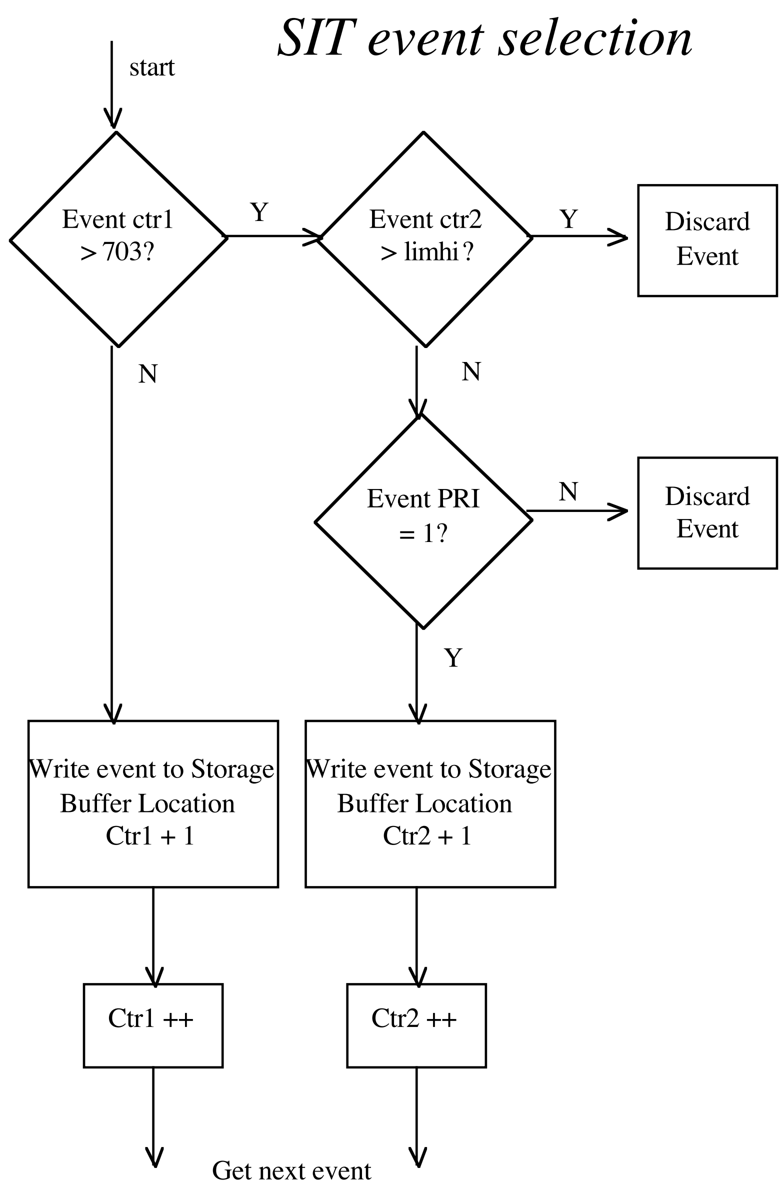
Figure 5. Same as fig. 3 except showing priority assignment.

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. 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 = high)	1
Total	32



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

6/14/02

Figure 6. Block diagram of the PHA event storage.

8. Data packets

All telemetry data is formatted into CCSDS compliant 272-byte packets. SIT data is contained in 4 packet types that are distinguished by an Application ID (APID) number which is carried in an 11-byte header for each packet along with timing and other information. RATE packets (APID 605); PHA packets (APIDs 606-616), Beacon (APID 624) and Housekeeping (APID 577) packets are telemetered once per 60 s.

At the end of the 60 second interval, the rate data is compressed (24→16 bits) before being stored in the RATE packet. The PHA storage buffer is transferred to a readout buffer and its contents are stored in 11 packets. The PHA and RATE packets contain SIT data only. Housekeeping information (20 bytes) is telemetered with other SEP housekeeping information in the HK packet. Beacon rates (24 bytes) from SIT are combined with other SEP beacon rates and telemetered in the Beacon packet. Table 5 lists each packet type containing SIT data, and the corresponding data rates. The storage formats for each packet type are given in the Appendices. (For testing with the GSE the HK and beacon data are put into packets with different numbers; see Appendices for further details)

Table 5. Packet contents

Packet type	APID	Size (bytes)
NOTE: all packets begin with The 11 byte CCSDS header, And have a 1-byte packet Checksum at the end		
PHA – 11 per 60 s interval 64 events per packet … No. of PHA events in pkt	606-616	11 x 272
RATE – 1 per 60 s interval 8 discriminator rates 116 Matrix Rates + HVSTEP … + status of TOFERROR, HVENABLE, EONLY, JUNK, and LIMHI	605	1 x 272
Beacon rates -- 1 per 60 s 12 beacon rates	624 (part)	24
Housekeeping -- 1 per 60 s Major frame number; TOF gain cal * 2048; TOF call offset * -64 TOF cal error flag + 8 analog HK values + Software version + Lookup table checksum	577 (part)	20
Total		**3308 bytes/60 sec (441 bits/s)**

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 - single bit commands that control a single function in the front-end logic.

10.1.1.1 HV Enable - (HVENABLE) enables the high voltage power supply

1=enable, 0 = disable, turn-on state = 0,
Usage: 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
Usage: diagnostic or in case of failure of TOF system

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 - (HVLEVEL) sets the top voltage out of the HVPS

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

Usage: 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.

10.2 COMMANDS TO THE MISC

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

10.2.1 State Commands - commands that set the MISC operating mode

10.2.1.1 TOF Error Events (TOFERROR): 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 (software versions 06 02 and later)

Usage: diagnostic and error recovery

10.2.1.2 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. 6). The default value of LIMHI is 500, but any value may be set by command (10 bits).

10.2.1.3 Enable transmission of ROM box = 0 events: (JUNK)

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 - commands that change contents of MISC memory

10.2.2.1 Look-Up Tables -

SIT event-processing look-up tables can be re-loaded from the ground; however, the flight MISC code will contain a default set of tables built-in. If new tables are loaded, they will need to replace the ones currently in use.

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 8)

Table 6. Command status

Associated Command Name*	Item	Size (bits)	State at turn on	Read out byte in Rate Packet (APID 605)
HVLEVEL x	HV step	8	0	260
TOFERROR x	enable transmission of events with TOF error bit on (1=enable)	1	0	261
HVENABLE x	enable HV (1=enable)	1	0	261
EONLY x	Analyze SSD only (1 = enable, 0 = require VS)	1	0	261
JUNK x	enable events with ROM box = 0 (0 = not transmitted; = 1 transmit)	1	0	261
LIMHI x	LIMHI	10	500	262-263

* the “x” following the command name is the numerical value command is set to

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. See Appendices 10 and 15 for housekeeping location in telemetry, and conversions.

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,

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

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

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

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

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

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:

2^16 * [f_m = (alog(amass)) + 1) * (128/7)] * 2^16

$$= (alog(essd) - alog(einc) + 1) * (128/7) \;] * 2^{16}$$
$$= (2^{16}*alog(essd) - 2^{16}*alog(einc) + 2^{16}) * (128/7) \;] \qquad (A1\text{-}3a)$$

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

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:

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

and for low gain (gain bit = 1)

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

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

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

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,

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

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,

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

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 Appendix 2. 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 -- FLIGHT LOOKUP TABLE DATES AND CHECKSUMS

Below are dates for flight lookup hex tables, and the associated checksums:

Unit	Date generated	Dates in use	Checksum (hex)	Checksum (decimal)
ETU - fm1 - fm2	060502	ETU: continuous Fm1: thru 9/13/05 19:12:43 Fm2: thru 9/05	927143	9597251
Fm1	060502 - ETU	... thru 9/13/05	927143	9597251
	090105	9/13/05 to 12/15/05	19750	104272
	092205	12/15/05 to 6/7/06	5F96DA	6264538
	042806	6/7/06 to 3/14/07	52A82E	5417006
	030507	3/14/07 ...	953589	9778569
Fm2	060502 - ETU	... thru 9/16/05	927143	9597251
	090605	9/16/05 to 12/15/05	F61150	16126288
	092205	12/15/05 to 6/7/06	542BC6	5516230
	4/28/06	6/7/06 to 3/14/07	46E9B7	4647351
	030507	3/14/07...	6E496A	7227754

Notes:
The checksum is the low order 24 bits of the sum of all four flight tables: SSDHI, SSDLO, TOF, and RATE and PRIORITY MATRIX.

Checksums can be calculated using program table_checksum (see Appendix 18 for further details)

TABLE A2-2 -- SSDHI INPUT FILE CONTENTS

USED when PHA gain bit = 0

Line number	Contents
1	high gain offset
2	low channel limit (discard if <5)
3	high channel limit (=<2048)
4	creation date: MMDDYY
5	Flight unit number (1 or 2)
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., 030507 (Mar 5, 2007)
version number: integer

Example: first several entries of the SSDHI portion of the table SIT_FM1_TABLES_030507.HEX(note date entry in line 4 in table is in decimal; all other entries are in hex):

Line	HEX value	(Decimal value)
1	080000	2^16
2	000005	5
3	000800	2048
4	030507	--
5	000001	1
6	000000	0
7	000000	0
8	000000	0
9	…etc	…etc

<u>Note: ONLY the HEX values are written out by the table generator program.</u>

TABLE A2-3 -- SSDLO INPUT FILE CONTENTS

USED when PHA gain bit = 1

Line number	Contents
1	low gain offset
2	low channel limit (discard if <5)
3	high channel limit (=<2048)
4	creation date: MMDDYY
5	Flight unit number (1 or 2)
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., 030507 (Mar 5, 2007)
version number: integer

Example: first several entries of the SSDLO section of the table SIT_FM1_TABLES_030507.HEX(note date entry in line 4 in table is in decimal; all other entries are in hex):

Line	HEX value	(Decimal value)
1	080000	2^16
2	000005	5
3	000800	2048
4	030507	--
5	000001	1
6	000000	0
7	000000	0
8	000000	0
9	…etc	…etc

Note: ONLY the HEX values are written out by the table generator program.

TABLE A2-4 -- TOF INPUT FILE CONTENTS

Line number	Contents
1	tof offset
2	low channel limit (discard if <5)
3	high channel limit (=<512)
4	creation date: MMDDYY
5	Flight unit number (1 or 2)
6	tof(6)
7	tof(7)
...	
...	
512	tof(512)

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

$$tof\,(N) = (\ln(0.021 * t * t) + 8) \times 2^{16} \qquad \text{(A2-3)}$$

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., 030507 (Mar 5, 2007)
version number: integer

Example: first several entries of the tof portion of the table SIT_FM1_TABLES_030507.HEX (note date entry in line 4 in table is in decimal; all other entries are in hex):

Line	HEX value	(Decimal value)
1	080000	0
2	000005	5
3	0001FF	511
4	030507	--
5	000001	1
6	04034D	262989
7	047A97	293527
8	04DB46	318278
9	…etc	…etc

Note: ONLY the HEX values are written out by the table generator program.

TABLE A2-5 -- 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 (fm1 version of 4/28/06; cells decoded using Excel spreadsheet “table_cell_decoder.xls):

Line No.	Cell contents	Items in cell		
		Beacon rate #	Priority	Matrix rate #
0	7	0	0	7
1	7	0	0	7
2	7	0	0	7
3	7	0	0	7
…	…			
1358	7	0	0	7
1359	7	0	0	7
1360	00006D	0	0	109
1361	00006D	0	0	109
1362	00006D	0	0	109
…	…			7
2217	7	0	0	7
2218	7	0	0	7
2219	0000AE	0	1	46
2220	0000AE	0	1	46
2221	0000AE	0	1	46
…	…			
3638	0005B0	5	1	48
3639	0005B0	5	1	48
3640	0005C0	5	1	64
3641	0005C0	5	1	64
3642	0005C0	5	1	64
3643	0005C0	5	1	64
3644	0005C0	5	1	64
3645	0005C0	5	1	64
3646	0005C0	5	1	64
3647	0000CF	0	1	79
3648	0000CF	0	1	79
…	…			
16381	7	0	0	7
16382	7	0	0	7
16383	7	0	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 (table version of 4/28/06):

Matrix Rate Box No.	UCB L1 Flux No.	title or element	Emin	Emax	Mass min	Mass max	Mass avg	Z	Pri (0 = low)
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	--	'discard'	0	0	0	0	0	0	
6	--	'out bnds'	0	0	0	0	0	0	
7	--	'Junk'	0	0	0	0	0	0	
8	1	'H'	0.1600	0.2263	0.5	2.3	1	1	0
9	2	'H'	0.2263	0.3200	0.5	2.3	1	1	0
10	3	'H'	0.3200	0.4525	0.5	2.3	1	1	0
11	4	'H'	0.4525	0.6400	0.5	2.3	1	1	0
12	5	'H'	0.6400	0.9051	0.5	2.3	1	1	0
13	6	'H'	0.9051	1.2800	0.5	2.3	1	1	0
14	7	'H'	1.2800	1.8102	0.5	2.3	1	1	0
15	8	'H'	1.8102	2.5600	0.5	2.3	1	1	0
16	9	'H'	2.5600	3.6204	0.5	2.3	1	1	0
17	10	'H'	3.6204	5.1200	0.5	2.3	1	1	0
18	11	'H'	5.1200	7.2408	0.5	2.3	1	1	0
19	12	'H'	7.2408	10.2400	0.5	2.3	1	1	0
20	13	'3He'	0.1600	0.2263	2.3	3.5	3	2	0
21	14	'3He'	0.2263	0.3200	2.3	3.5	3	2	0
22	15	'3He'	0.3200	0.4525	2.3	3.5	3	2	0
23	16	'3He'	0.4525	0.6400	2.3	3.5	3	2	0
24	17	'3He'	0.6400	0.9051	2.3	3.5	3	2	0
25	18	'3He'	0.9051	1.2800	2.3	3.5	3	2	0
26	19	'3He'	1.2800	1.8102	2.3	3.5	3	2	0
27	20	'3He'	1.8102	2.5600	2.3	3.5	3	2	0
28	21	'3He'	2.5600	3.6204	2.3	3.5	3	2	0
29	22	'3He'	3.6204	5.1200	2.3	3.5	3	2	0
30	23	'4He'	0.0400	0.0566	3.5	8.0	4	2	0
31	24	'4He'	0.0566	0.0800	3.5	8.0	4	2	0
32	25	'4He'	0.0800	0.1131	3.5	8.0	4	2	0
33	26	'4He'	0.1131	0.1600	3.5	8.0	4	2	0
34	27	'4He'	0.1600	0.2263	3.5	8.0	4	2	0
35	28	'4He'	0.2263	0.3200	3.5	8.0	4	2	0
36	29	'4He'	0.3200	0.4525	3.5	8.0	4	2	0

Matrix Rate Box No.	UCB L1 Flux No.	title or element	Emin	Emax	Mass min	Mass max	Mass avg	Z	Pri (0 = low)
37	30	'4He'	0.4525	0.6400	3.5	8.0	4	2	0
38	31	'4He'	0.6400	0.9051	3.5	8.0	4	2	0
39	32	'4He'	0.9051	1.2800	3.5	8.0	4	2	0
40	33	'4He'	1.2800	1.8102	3.5	8.0	4	2	0
41	34	'4He'	1.8102	2.5600	3.5	8.0	4	2	0
42	35	'4He'	2.5600	3.6204	3.5	8.0	4	2	0
43	36	'4He'	3.6204	5.1200	3.5	8.0	4	2	0
44	37	'4He'	5.1200	7.2408	3.5	8.0	4	2	0
45	38	'4He'	7.2408	10.2400	3.5	8.0	4	2	0
46	39	'C'	0.0283	0.0400	8	14	12	6	1
47	40	'C'	0.0400	0.0566	8	14	12	6	1
48	41	'C'	0.0566	0.0800	8	14	12	6	1
49	42	'C'	0.0800	0.1131	8	14	12	6	1
50	43	'C'	0.1131	0.1600	8	14	12	6	1
51	44	'C'	0.1600	0.2263	8	14	12	6	1
52	45	'C'	0.2263	0.3200	8	14	12	6	1
53	46	'C'	0.3200	0.4525	8	14	12	6	1
54	47	'C'	0.4525	0.6400	8	14	12	6	1
55	48	'C'	0.6400	0.9051	8	14	12	6	1
56	49	'C'	0.9051	1.2800	8	14	12	6	1
57	50	'C'	1.2800	1.8102	8	14	12	6	1
58	51	'C'	1.8102	2.5600	8	14	12	6	1
59	52	'C'	2.5600	3.6204	8	14	12	6	1
60	53	'C'	3.6204	5.1200	8	14	12	6	1
61	54	'C'	5.1200	7.2408	8	14	12	6	1
62	55	'C'	7.2408	10.2400	8	14	12	6	1
63	56	'O'	0.0400	0.0566	14	19	16	8	1
64	57	'O'	0.0566	0.0800	14	19	16	8	1
65	58	'O'	0.0800	0.1131	14	19	16	8	1
66	59	'O'	0.1131	0.1600	14	19	16	8	1
67	60	'O'	0.1600	0.2263	14	19	16	8	1
68	61	'O'	0.2263	0.3200	14	19	16	8	1
69	62	'O'	0.3200	0.4525	14	19	16	8	1
70	63	'O'	0.4525	0.6400	14	19	16	8	1
71	64	'O'	0.6400	0.9051	14	19	16	8	1
72	65	'O'	0.9051	1.2800	14	19	16	8	1
73	66	'O'	1.2800	1.8102	14	19	16	8	1
74	67	'O'	1.8102	2.5600	14	19	16	8	1
75	68	'O'	2.5600	3.6204	14	19	16	8	1

Matrix Rate Box No.	UCB L1 Flux No.	title or element	Emin	Emax	Mass min	Mass max	Mass avg	Z	Pri (0 = low)
76	69	'O'	3.6204	5.1200	14	19	16	8	1
77	70	'O'	5.1200	7.2408	14	19	16	8	1
78	71	'O'	7.2408	10.2400	14	19	16	8	1
79	72	'NeS'	0.0400	0.0566	19	36	24	12	1
80	73	'NeS'	0.0566	0.0800	19	36	24	12	1
81	74	'NeS'	0.0800	0.1131	19	36	24	12	1
82	75	'NeS'	0.1131	0.1600	19	36	24	12	1
83	76	'NeS'	0.1600	0.2263	19	36	24	12	1
84	77	'NeS'	0.2263	0.3200	19	36	24	12	1
85	78	'NeS'	0.3200	0.4525	19	36	24	12	1
86	79	'NeS'	0.4525	0.6400	19	36	24	12	1
87	80	'NeS'	0.6400	0.9051	19	36	24	12	1
88	81	'NeS'	0.9051	1.2800	19	36	24	12	1
89	82	'NeS'	1.2800	1.8102	19	36	24	12	1
90	83	'NeS'	1.8102	2.5600	19	36	24	12	1
91	84	'NeS'	2.5600	3.6204	19	36	24	12	1
92	85	'NeS'	3.6204	5.1200	19	36	24	12	1
93	86	'NeS'	5.1200	7.2408	19	36	24	12	1
94	87	'NeS'	7.2408	10.2400	19	36	24	12	1
95	88	'Fe'	0.0283	0.0400	36	80	56	26	1
96	89	'Fe'	0.0400	0.0566	36	80	56	26	1
97	90	'Fe'	0.0566	0.0800	36	80	56	26	1
98	91	'Fe'	0.0800	0.1131	36	80	56	26	1
99	92	'Fe'	0.1131	0.1600	36	80	56	26	1
100	93	'Fe'	0.1600	0.2263	36	80	56	26	1
101	94	'Fe'	0.2263	0.3200	36	80	56	26	1
102	95	'Fe'	0.3200	0.4525	36	80	56	26	1
103	96	'Fe'	0.4525	0.6400	36	80	56	26	1
104	97	'Fe'	0.6400	0.9051	36	80	56	26	1
105	98	'Fe'	0.9051	1.2800	36	80	56	26	1
106	99	'Fe'	1.2800	1.8102	36	80	56	26	1
107	100	'Fe'	1.8102	2.5600	36	80	56	26	1
108	101	'Fe'	2.5600	3.6204	36	80	56	26	1
109	102	'UH'	0.04	0.0800	80	180	132	54	0
110	103	'UH'	0.08	0.1600	80	180	132	54	0
111	104	'UH'	0.16	0.3200	80	180	132	54	0
112	105	'UH'	0.32	0.6400	80	180	132	54	0
113	106	'UH'	0.64	1.2800	80	180	132	54	0
114	107	'UH'	1.28	2.5600	80	180	132	54	0

Matrix Rate Box No.	UCB L1 Flux No.	title or element	Emin	Emax	Mass min	Mass max	Mass avg	Z	Pri (0 = low)
115	--	'bkgd'	0.06	0.5000	180	400	290	80	0
116	--	'bkgd'	0.5	3.0000	180	400	290	80	0

Note: boxes 1-7, and the 2 bkgd rates are not calculated as part of the level-1 fluxes at UCB, since they do not return rates for a specific species and energy interval.

APPENDIX 4 -- BEACON MATRIX RATE ASSIGNMENTS

Beacon box number per Dick Mewaldt memo/spreadsheet dated 12/8/01; updated energy ranges 8/26/05

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'	0.04	0.12	0.1	2.0	8	4	2
2	'4He'	0.12	0.36	0.22	2.0	8	4	2
3	'4He'	0.36	1.08	0.23	2.0	8	4	2
4	'4He'	1.08	3.24	0.1	2.0	8	4	2
5	'CNO'	0.04	0.12	1.	8	19	14	8
6	'CNO'	0.12	0.36	1.	8	19	14	8
7	'CNO'	0.36	1.08	1.	8	19	14	8
8	'CNO'	1.08	3.24	1.	8	19	14	8
9	'Fe'	0.04	0.12	1.	40	60	56	26
10	'Fe'	0.12	0.36	1.	40	60	56	26
11	'Fe'	0.36	1.08	1.	40	60	56	26
12	'Fe'	1.08	3.24	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 post launch values) are given in the table.

$A\Omega = 0.30\ cm^2$-sr

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 15).

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	Spacecraft APID (hex)	Packet Description	SIT GSE APID (hex)
576	240	Command response	--
577	241	housekeeping (from SEP Central)	618, 26A
605	25D	RATE packet	25D
606	25E	PHA packet #1	25E
607	25F	PHA packet #2	25F
608	260	PHA packet #3	260
609	261	PHA packet #4	261
610	262	PHA packet #5	262
611	263	PHA packet #6	263
612	264	PHA packet #7	264
613	265	PHA packet #8	265
614	266	PHA packet #9	266
615	267	PHA packet #10	267
616	268	PHA packet #11	268
617	269	test mode 2	269
--	--	(empty packet from GSE)	623. 26F
624	270	beacon rates (from SEP Central)	619, 26B

APPENDIX 7 -- APID 576 - COMMAND RESPONSE

This packet contains all command echoes from SEP central; it is only put out when commands are received.

Table A7-1 -- Command response packet

note: SIT software for this packet looks for the cue: SIT>

Byte #	Description	UMd GSE to Winmac hex Byte #
1-11	CCSDS header	--
12-271	Command ASCII string	
272	checksum	261

APPENDIX 8 -- APID 577 -- HK PACKET CONTENTS

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 A8-1 -- 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	

Location of items in HK packet (note that the 4-bit components of each byte are reversed):

```
06/06/07 22:11:26  ; ApId:  577  Ahead
  a 41 c0 1d  1  9 5b 19 ad 8e c0 bd 48 43 5a 4f
 4a 42 58 49  f d5 56 fb bc 59 54 4d 4c 57 4f 4f
 40 10  f f8 eb 98 9c  1 31 1c  1 b0  0  1  0  7
 32 8c  0 60  0  3  0  0  0  2  5  0  0  0  0 57
  2 1b  0 f2 75 73 42  5 f0  0  0  0  0  0  8  2
  0 80 20  8  2  0 80 20  8  2  1 90 67  4 81 20
 48 12  4 81 20 48 12  4 81 20 48 12  4 c1 20 48
 13  4 81 20 48 12  4 81 20 48 12  4 81 20 48 12
  4 81 20 80 20  8  2  0 80 20  8  2  0 80 20 19
  6 e0 3f 3f 3f 3f  2 f4  0  0  0  0  0  d  0  0
  d  0  0  d  0  0  d  0  0  d  0  0  d  0  0  d
  0  0  d  0 1b  0 27 52 c7  3  0 fe 3b 46 4c 58
 83 7e 69  2  6 2e a8 52  0  0  0  0  0  0  0  0
  0  0  0  0  0  0  0  0 c2 c3 c3 9e 81 81 81 c2
 d7 ea 16 ed 12 e7 14 19 e8 c2 f1 f4 c2 f1 f6 c0
 d2  f  0 db  d  0 11  0 11  0  f  0  d  0  0  0
  4  0  1  0  5  0  2  0  6  0  3  0  7  0  0 1e
```

41: byte 2, portion of APID; APID is 512 + byte 2 = 512 + 41H = 512 + 65 = 577

2 6 : bytes 196-197: software version (06 02)

2e a8 52: bytes 198-199-200: lookup table checksum (52A82E)

APPENDIX 9 -- APID 605 - RATE PACKET CONTENTS

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

Table A9-1 -- 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 -- (Pri 0)	
30-31	MR2 (Pri 1)	
32-33	MR3 (Hi ramp) ... etc	
34-35	MR4	
36-37	MR5	
...	...	
258-259	MR116	
260	hvstep	HVLEVEL
261	4 1-bit flags: bit 0 (lsb): 0 = TOF error events dropped 1 = TOF error events transmitted 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	 TOFERROR HVENABLE EONLY JUNK
262-263	LIMHI	LIMHI
264-271	spare	
272	checksum	261

APPENDIX 10 -- APIDs 606-616 - PHA PACKET CONTENTS -

Table A10-1 -- 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 11 -- APID 617 - TEST MODE 2 PACKET CONTENTS

NOTE: THIS PACKET TYPE WAS NEVER IMPLEMENETED

Table A11-1 -- Test Mode 2 packet

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

APPENDIX 12 -- APID 623 -- GSE EMPTY PACKET CONTENTS

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 -- APID 624 - BEACON RATE PACKET CONTENTS

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 A13-1 -- 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 14 -- Ground Receipt Header HEADER

Table 16. Ground Receipt Header Format (1 of 2)

GROUND RECEIPT HEADER (1 of 2)				
Contents	Size (bits)	Size (bytes)	Type	Units/Range
Size	16	2	Binary	Size of this object including headers in bytes, unsigned integer in MSB first order (max = 65535)
Data Type	8	1	Binary	type of data object 0 = "00000000" = EOT 2 = "00000010" = STP 3 = "00000011" = PTP
GRT Usage	8	1	Binary	Defines how ERT/GRT time should be interpreted. Expected value is 010xxxxx. 1xxxxxxx indicates ERT is invalid
GRH Version ID	8	1	Binary	Version Identifier associated with this GRH format
Spacecraft ID	16	2	Binary	Ahead = 0XEA = "0000 0000 1110 1010" Behind = 0xEB = "0000 0000 1110 1011"
Ground Receipt TIme (GRT) Epoch Day	16	2	Binary	Days since Jan 1, 1958; Range = 0-65,535; Binary Unsigned Integer
GRT milliseconds of day	32	4	Binary	Milliseconds-of-day since midnight UTC; Range = 0 to 86,400,000 (allows for one leap second) Binary unsigned integer
GRT extended resolution	16	2	Binary	Tenths of microseconds since the millisecond; range 0-9,999.
spare bits	6	0.750	Binary	
Frame Quality Flag	1	0.125	Binary	0 = Data Suspect 1 = Data Correct
Archive Flag	1	0.125	Binary	0 = Do Not Archive 1 = Archive

FSCM NO.	SIZE	DRAWING NO.	REV.
88898	A	7381-9045	B
SCALE	DO NOT SCALE PRINT	SHEET 52 of 68	

GROUND RECEIPT HEADER (continued)

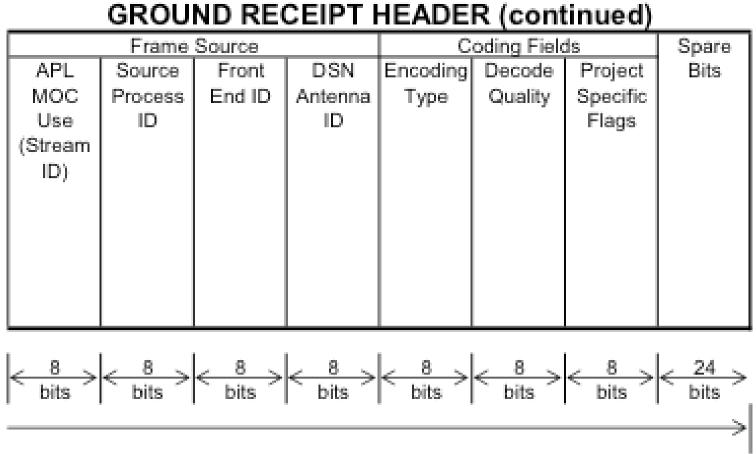


Figure 16. Ground Receipt Header Data Structure Diagram (2 of 2)

Table 17. Ground Receipt Header Format (2 of 2)

GROUND RECEIPT HEADER (2 of 2)				
Contents	Size (bits)	Size (bytes)	Type	Units/Range
APL MOC Use (Stream ID)	8	1	Binary	
Frame Source Process ID	8	1	Binary	Frame Source Type and Frame Source Index
Front-end Identifier	8	1	Binary	"Front End" identifiers map either to APL MOC, Front Ends, or DSN facilities
Frame Source: DSN Antenna ID	8	1	Binary	DSN Station Identifier
Encoding Type	8	1	Binary	Bit 0 is MSB Bit 0 = 1 No encoding Bit 1 = 1 RS encoding Bit 2 = 1 Convolutional encoding Bit 3 = 1 CRC used Bit 4 = 1 Turbo used Bits 5 - 7 unused
Decode Quality	8	1	Binary	Bit 0 is MSB Bits 0 - 3, 7 unused Bit 4 Decoder success flag; passed=1 Bit 5 CRC check status flag; passed=1 Bit 6 Output type;decoded data=0
Project Specific Flags	8	1	Binary	Not used by STEREO
spare bits	24	3	Binary	Not used by STEREO
TOTAL SIZE (bits & bytes)	**208**	**26**		

FSCM NO.	SIZE	DRAWING NO.	REV.
88898	A	7381-9045	B
SCALE	DO NOT SCALE PRINT	SHEET 53 of 68	

APPENDIX 15 -- CCSDS HEADER

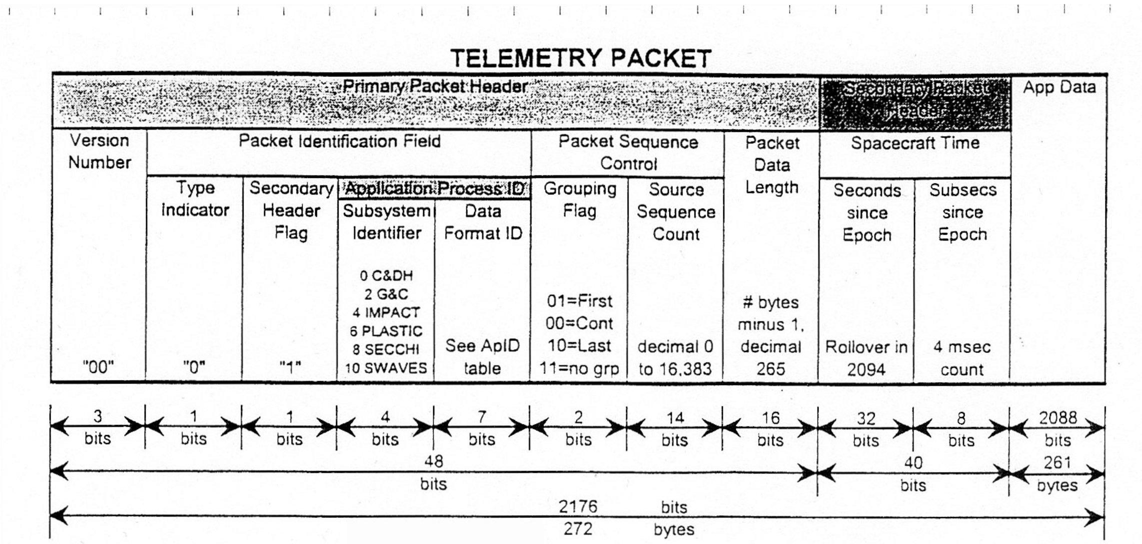


Figure 13. CCSDS Telemetry Packet Data Structure Diagram

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 16 -- RATE DECOMPRESSION ALGORITHM

Each 2 byte compressed rate is decoded as follows:

Table A-16-1 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; e-mail from Kristin Wortman 9/19/05:

To extract the COUNTS value from a compressed rate, form

TEST = BYTE1 + 256*BYTE2

If TEST less than 4096, then COUNTS = TEST

If TEST is greater than or equal to 4096, then form

mantissa = bits M1-M11
exponent = bits E1-E5

then, COUNTS = (mantissa + 2048)*2^(exponent - 1)

Note: in the software decompression, since the original data is from a 24-bit counter, if the decompressed COUNTS is > 2^24, the COUNTS is given as FILL (-1 or TBD). This prevents data errors from producing large numbers from the above algorithm (up to 4095*2^30). See Andrew Davis e-mail, 11/23/05.

APPENDIX 17 -- ANALOG HOUSEKEEPING CALIBRATION

The conversion from channel number Ichan to analog value A for each housekeeping items 0, and 4-7 is given by:

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

where:

Table A-17-1 Analog Housekeeping Calibration

		fm1		fm2	
Item no.	Name	a0	a1	a0	a1
0	HV	4133.5260	-16.5870	4133.5260	-16.5870
1	DTOF temp	37.4581	-0.3146	49.5024	-0.4885
2	Foil temp	37.4581	-0.3146	49.5024	-0.4885
3	SSD temp	45.7564	-0.4188	49.5024	-0.4885
4	+3.3V	5.1000	-0.0200	5.1000	-0.0200
5	+2.5V	5.1000	-0.0200	5.1000	-0.0200
6	+5 Dig V	10.2000	-0.0400	10.2000	-0.0400
7	+6V	10.1911	-0.0412	10.1911	-0.0412
		V_ref_ch	V_slope	V_ref_ch	Vslope
--	6V temp correction	101.5	-2.68	100.	-2.68

HV 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; this HV calibration is used for both fm1 and fm2 units

TEMP cal: see notebook 12/27-28/06 and referenced notes; for flight data these calibrations depend on of the 6V line. To find the correct temperature, the average channel number of the temperature values is corrected for the difference between the 6V line channel number vs. the 6V line channel number at the reference value:

$$T_{corrected} = a0 + a1 * (Ichan_{temp} - V\_slope \times (Ichan_{6V} - v\_ref\_ch_{6V}))$$

Note that the ±1 channel jitter on the +6V will cause a ~±1° jitter in the corrected temp. (Last thermister calibration update: 12/27/06)

APPENDIX 18 -- 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 fm1 tables of 042806 the values are: :

Directory $USER:[MASON.STEREO.FLIGHT_TABLES.FM1]

SIT_FM1_TABLES_042806.HEX;1
411 28-APR-2006 15:11:58.26 [ULEIS,MASON]

Total of 1 file, 411 blocks.
ULEIS$ run [mason.stereo.flight_tables.generator]table_checksum
Enter input filename:SIT_FM1_TABLES_042806.HEX
table 1 decimal checksum = 1346806691
table 2 decimal checksum = 1629566696
table 3 decimal checksum = 6265819
table 4 decimal checksum = 394998216
total checksum: 3377637422
low order 24 bits of checksum: 5417006 decimal
low order 24 bits of checksum: 52A82E hex <---THIS IS THE TELEMETERED VALUE

(program $user:[MASON.STEREO.FLIGHT_TABLES.generator]table_checksum is used to generate the above checksum).

APPENDIX 19 -- OPERATING HOUSEKEEPING LIMITS

Reference: PW notes; Andrew Davis files SEP_HK_T.xls; SEP_HK_S.pdf (dated Feb 7, 2006)

Table A-19-1 SIT Operating temperature limits

IDENTIFIER	Units	RL	YL	YH	RH	DESCRIPTION
SIT_HVMon	V	-120	-100	3300	3400	HV Monitor
SIT_DTOF_Temp	C	-50	-45	55	65	DTOF Temperature
SIT_Foil_Temp	C	-50	-45	35	38	Foil Temperature
SIT_SSD_Temp	C	-50	-45	35	38	SSD Temperature
SIT_P33Mon	V	3	3.1	3.4	3.5	+3.3 Volts
SIT_P25Mon	V	2.25	2.35	2.55	2.65	+2.5 Volts
SIT_P5DMon	V	4.6	4.8	5.3	5.5	+5D Volts
SIT_P6Mon	V	5.6	5.8	6.3	6.5	+6 Volts

Note: YH and RH limits for foil and ssd temp were increased by 5°C in Jan 2006 after installation of Micron ion-implant SSDs. File sent by Andrew had the prior limits.
Mod HV limits 2/7/06 based on HV settings of b8 during alpha runs Nov-Dec 2005.

APPENDIX 20 -- FLIGHT SOFTWARE VERSIONS

Version	First used	Mods from prior version
07 15	7/15/04	First full-up version tested with ETU (logbook SIT 8, p 46)
09 03	09/03/2004	Fix HVRAMP bug (logbook SIT 8, p 106)
06 02	06/07/06 (in S/C) tested in ETU 6/2/06	(1) Fix race condition for event processing when MF flag received (2) set turn-on state for TOFERROR flag to 0 (STEREO notebook #4, 6/2/06)