Document No. STEREO-CIT-008.A

High Energy Telescope
Interface Control Document
for the
Solar Energetic Particle
Central Electronics

HET-SEP_Central ICD

Revision A

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Table of Contents:

1. Scope and Revision History

This document describes electrical hardware interfaces and timing protocols for commands, data, discrete and power signals between the HET instrument and SEP central electronics (SEP_Central) as part of the SEP/IMPACT suite aboard each of the two STEREO spacecraft.
For details on software-related aspects of the HET-SEP_Central interface see the reference document 2.2.

The interfaces are conducted via internal unshielded rigid-flex harness that is 8 cm (3") long and terminated on the SEP_Central side by a Nanonics 51-pin, 2-row dualobe plug connector. Pin redundancy is not mandatory, yet highly desirable.

Rev.	Date	Description
-	08/20/02	Initial release
A	10/23/02	Added major timing, packet and power information

2. Applicable Documents

2.1 STEREO Mission Operations Center (MOC) to Payload Operations Center (POC) and to STEREO Science Center (SSC) Interface Control Document (ICD)
APL Drawing No. 7381-9045, Rev. A
http://sprg.ssl.berkeley.edu/impact/dwc/ICD/MOC-POC ICD 07-10-2002.pdf

2.2 SEP Commanding and Users Manual Document No. STEREO-CIT-007.A
ftp://mussel.srl.caltech.edu/pub/stereo/docs/SEP_CommandingUserManual_A.pdf

2.3 Interface Control Document (ICD) for the IMPACT Investigation
APL Drawing No. 7381-9012, Rev B, available at APL STEREO website

2.4 IMPACT LVPS Requirements, Rev. C
http://sprg.ssl.berkeley.edu/impact/dwc/ICD/LVPSRequirements_C.pdf

3. Command Interface

The Command Interface shall be used to transfer the following:

A. Commands from SEP_Central to HET . . . 3.1 – 3.2.1
B. Command responses from HET to SEP_Central . . 3.3 – 3.4.1
C. Frame sync pulses from SEP_Central to HET . . 3.5 – 3.6.1
D. Reset pulses from SEP_Central to HET . . . 3.7 – 3.8.1
E. Boot code from SEP_Central to HET . . . 3.9

A. Transfer of commands from SEP_Central to HET

3.1 Protocol. Transfer of commands from SEP_Central to HET shall take place according to the Serial Data/Command Protocol shown in Figure 1 below.

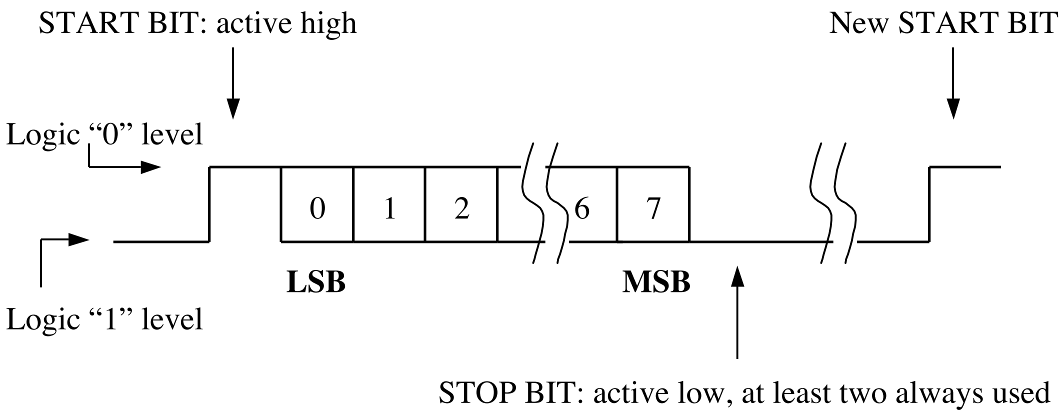


Figure 1 - Serial Data/Command Protocol
(Signal polarity shown at interface connector pins)

Note: Nominal baud rate = 57.6 kbaud
High baud rate was chosen to allow boot code transfer in a reasonably short time.

Actual rate on HET side = 57.97101 kbaud - generated from 32 MHz / (8*69)

Actual rate on SEP_Central side = 57.14286 kbaud - from 16 MHz / (8*35)

3.2 Signal Description.

3.2.1 HET CMD IN*. This 0 to +5 V digital signal is used to transfer commands from SEP_Central to HET. SEP_Central shall generate this signal. Its return line is HET MSTR RTN, which is tied to the signal ground (local chassis) on the SEP_Central side, while on the HET side it is separated from the local signal ground (local chassis) by 50 Ω. See appendix 8.1 for details of the I/F schematic.

B. Transfer of command responses from HET to SEP_Central

3.3 Protocol. Transfer of command responses from HET to SEP_Central shall take place according to the Serial Data/Command Protocol described in Figure 1 and Paragraph 3.1.

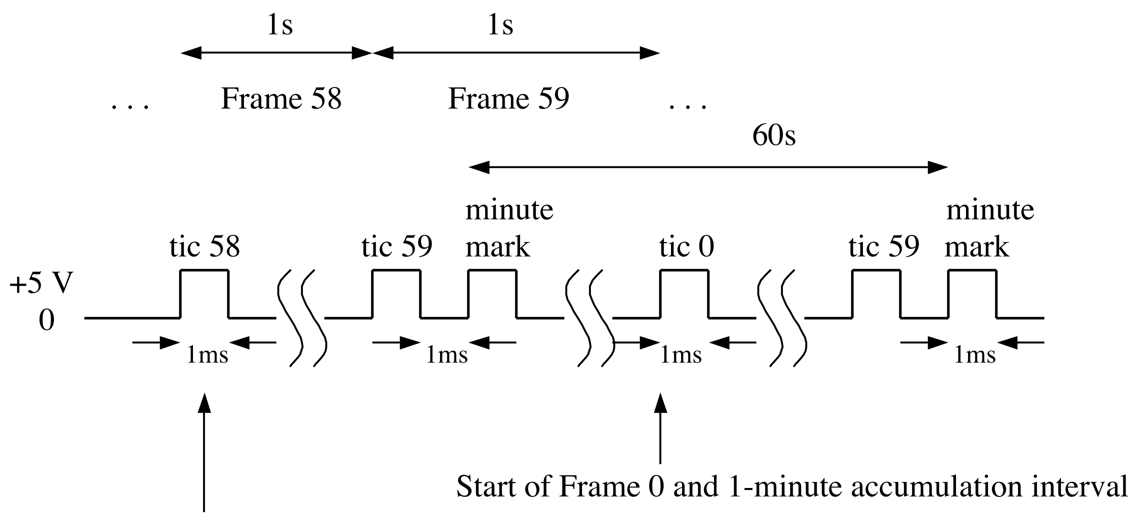
Note: In case of extremely long command responses (e.g., command table dump or memory dump) HET shall throttle the transfer rate of command responses so that SEP_Central buffer is not saturated.

3.4 Signal Description.

3.4.1 HET CMD OUT*. This 0 to +5 V digital signal is used to transfer command responses from HET to SEP_Central. HET shall generate this signal. Its return line is HET SUB RTN, which is tied to the signal ground (local chassis) on the HET side, while on the SEP_Central side it is separated from the local signal ground (local chassis) by 50 Ω. See appendix 8.1 for details of the I/F schematic.

C. Transfer of frame sync pulses from SEP_Central to HET

3.5 Protocol. Transfer of frame sync pulses from SEP_Central to HET shall take place according to the Frame Sync Protocol shown in Figure 2 below.



FRAME SYNC: active high, 1s period, nominally 1ms long; double-pulsed every 60s to provide the 1-minute mark

Figure 2 – Frame Sync Protocol
(Signal polarity shown at interface connector pins)

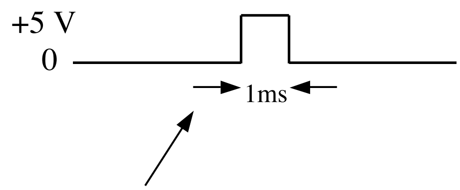
Note: Tic 0 follows the 1-minute mark by ~1 second and marks the beginning of Frame 0 as well as the beginning of 1-minute accumulation interval for HET.

3.6 Signal Description.

3.6.1 HET FRAME SYNC. This 0 to +5 V digital signal is used to transfer a frame-synchronizing signal from SEP_Central to HET. SEP_Central shall generate this signal. Its return line is HET MSTR RTN, which is tied to the signal ground (local chassis) on the SEP_Central side, while on the HET side it is separated from the local signal ground (local chassis) by 50 Ω. See appendix 8.1 for details of the I/F schematic.

D. Transfer of reset pulses from SEP_Central to HET

3.7 Protocol. Transfer of reset pulses from SEP_Central to HET shall take place according to the Reset Pulse Protocol shown in Figure 3 below.



RESET PULSE: active high, nominally 1ms long, non-periodic

Figure 3 – Reset Pulse Protocol
(Signal polarity shown at interface connector pins)

3.8 Signal Description.

3.8.1 HET RESET. This 0 to +5 V digital signal is used to transfer a reset signal from SEP_Central to HET in order to reset the HET Minimum Instruction Set Computer (MISC). SEP_Central shall generate this signal. Its return line is HET MSTR RTN, which is tied to the signal ground (local chassis) on the SEP_Central side, while on the HET side it is separated from the local signal ground (local chassis) by 50 Ω. See appendix 8.1 for details of the I/F schematic.

E. Transfer of boot code from SEP_Central to HET

3.9 Protocol. Transfer of boot code shall take place according to the Serial Data/Command Protocol described in Figure 1 and Paragraph 3.1.
For more details on this topic see the reference document 2.2.

4. Data Interface

The Data Interface is used for transfer of information from HET to SEP_Central. All HET data types (science, housekeeping and beacon) shall be formatted into CCSDS telemetry packets in order to be transferred over this interface.

4.1 Protocol. Transfer of data shall take place according to the Serial Data/Command Protocol described in Figure 1 and Paragraph 3.1.

Note: Nominal baud rate = 57.6 kbaud
High baud rate was chosen to allow data packet transfer in a reasonably short time.

4.2 Signal Description.

4.2.1 HET DATA OUT*. This 0 to +5 V digital signal is used to transfer data from HET to SEP_Central. HET shall generate this signal. Its return line is HET SUB RTN, which is tied to the signal ground (local chassis) on the HET side, while on the SEP_Central side it is separated from the local signal ground (local chassis) by 50 Ω. See appendix 8.1 for details of the I/F schematic.

4.3 CCSDS Packet.

4.3.1 Format Overview. Data transfer from HET to SEP_Central shall be carried out in the form of a standard 272-byte long CCSDS telemetry packet that consists of the following:

- 6-byte long Primary Packet Header (byte # 0-5, inclusive)
- 5-byte long Secondary Packet Header (byte # 6-10, inclusive)
- 261 bytes of Application Data (byte # 11-271, inclusive)

For a detailed CCSDS telemetry packet format description see appendix 8.4 below and the reference document 2.1.

HET shall transfer its data to SEP_Central in the form of complete packets with the content of the Primary Packet Header defined as follows:

- Byte 0: 00001010 (MSB on the left.)
- Byte 1: 01001110 (E.g., 24E = 010 0100 1110, part of an 11-bit APID.)
- Byte 2: 11xxxxxx (“No grouping” flag and Src. Seq. Ct. below.)
- Byte 3: xxxxxxxx (Source Sequence Count, total of 14 bits.)
- Byte 4: 00000001 (Packet Data Length, including Secondary Header,)
- Byte 5: 00001001 (in # of bytes–1, i.e., 265)

HET shall zero-fill the Secondary Packet Header (byte # 6-10, inclusive), as this part of the packet shall be filled-in by SEP_Central. The header contains 5 bytes of S/C time (4+1, i.e., truncated in the sub-seconds field from 2 bytes down to 1).

HET shall also zero-fill the Checksum Byte (byte # 271, the last byte of each CCSDS packet).
In the case of HET science data packets the Checksum Byte shall be filled-in by SEP_Central and set such that the arithmetic sum of all bytes in the packet, modulo 256, equals zero.
In the case of HET HK and beacon data packets, IMPACT IDPU shall calculate the checksum after the assembly of IMPACT-wide HK and beacon data packets.

4.3.2 APID and Rate Allocation. HET data packets shall carry an 11-bit APID (Application Process Identifier) in the hex range 24E-257 (inclusive), or 590–599 decimal. The APIDs shall be designated by HET and distributed among its various packet types, shown below with their rate allocations (note that the bit and byte rates do not include packet headers):

- HET science data (rates, events, etc.) 6 packets/min (208.8 bits/s)
- HET housekeeping data 1 packet/min (12 bytes/min)
- HET beacon data 1 packet/min (28 bytes/min)

4.3.3 Transfer Schedule. Using the protocols in Figures 1 and 2 above, data packet transfer from HET to SEP_Central shall be based on a once-per-second pulse (frame sync) where the beginning of each 1-minute period is marked by a double pulse. SEP_Central shall generate the frame sync pulses and ensure that the 1-minute marks are synchronized to the UT minute intervals. HET shall make use of its internal timers and interrupts tied to the frame sync pulses to schedule data packet transfers. Frames of each minute shall be numbered 0-59. Beginning of frame 0 shall coincide with tic 0 immediately following the 1-minute mark. HET basic data accumulation interval shall be 1 minute long, beginning at tic 0.

SEP_Central collects data from three MISC-equipped sensors (LET/HET/SIT) in an alternating cyclical manner during the first 200 ms of each frame dedicated to a packet transfer from that particular sensor. Thus every sensor has a total of 20 dedicated data-transmission frames in every minute. HET shall transmit at least one packet to SEP_Central within the initial 200-ms window following tic 0, 3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, 36, 39, 42, 45, 48, 51, 54 and 57.

Given the baud rate of 57.6 kbaud it takes ~52 ms to send one data packet. HET may send more than one packet during the 200-ms window or send a “dummy”, zero-filled, packet instead. HET data packets shall be transmitted over the entire 1-minute cycle (the regularity of packets helps in ground testing, e.g., with an oscilloscope triggering on the frame sync one can quickly verify the data content). SEP_Central shall not forward the zero-fill HET data packets to the IDPU. It would be beneficial if these zero-fill HET data packets were assigned a special pattern in order to be easily recognized by SEP_Central. For more details on this topic see the reference document 2.2.

HET data packets received by SEP_Central during a given accumulation minute (N) shall contain HET data collected during the prior minute (N-1) and shall be transmitted to the IMPACT IDPU during the following minute (N+1). SEP_Central shall fill-in the UT portion of all packets received during minute (N) with the UT code associated with tic 0 of minute (N-1). In other words, the UT code of a packet shall refer to the beginning of the minute during which its data was accumulated.

4.4 Special Data Modes.

4.4.1 Accelerator Testing Mode. SEP_Central shall pay attention to just one sensor (HET), which can then use nearly 57.6 kbaud bandwidth of the serial data line. The data format from the sensor can be anything in this mode, or it could be in the form of multiple packets/second. HET shall throttle the transfer rate to a maximum value that is TBD, but close to the limit imposed by the 57.6 kbaud rate.

4.4.2 Variable Packet Rate. The number of packets/minute generated by HET, as well as the number of HET packets passed on by the SEP_Central shall be commandable. This would allow HET to make use of available bandwidth should any other SEP sensor become disabled.

5. Discrete Signal Interface

5.1 Protocol. SEP_Central shall provide a pair of connections (2 lines) between the instrument connector (HET-J1) and the Spacecraft Thermal connector (SEP-J2) for the signals listed below. The two signals of the pair shall be routed close together to avoid the introduction of electric noise.

5.2 Signal Description.

5.2.1 HET S/C TEMP and HET S/C TEMP RTN. These are a pair of signals that connect to a spacecraft-monitored temperature sensor in the HET instrument (a modified “Minco Products” thermistor model S17624, flight part # S100480PFY72B, +/- 100 °C). The sensor is nominally powered by the S/C, with SEP_Central only providing a connection between the S/C and HET instrument. Selection of the sensor location in HET shall be coordinated with the SEP Thermal Engineer and in accordance with the reference document 2.3.

6. Power Interface

These signals are used to provide power to the HET instrument.

6.1 LVPS Protocol. SEP LVPS outputs listed below shall be shared among the SEP subsystems (LET, HET, SIT and SEP_Central) and regulated to +/- 5 % (half load to full load). High frequency (LVPS-generated) ripple on the secondary outputs shall be less than 10 mV peak-to-peak at full load, as per reference document 2.4.

6.2 Signal Description.

6.2.1 HET PWR RTN. This line provides a return path for all analog and digital power signals from HET to SEP_Central. It is connected to the local chassis in both HET and SEP LVPS, therefore serving as a signal ground to which all analog and digital voltages are referenced.

6.2.2 HET +13A. This line provides analog power at +13 V, primarily used in the local +5 V series regulator. Its maximum current draw during the steady-state operation shall not exceed 5 mA.

6.2.3 HET -13A. This line provides analog power at -13 V, primarily used in the –5 V reference generator. Its maximum current draw during the steady-state operation shall not exceed 1 mA.

6.2.4 HET +6A. This line provides analog power at +6 V, primarily used in the local +5 V series regulator. Its maximum current draw during the steady-state operation shall not exceed 15 mA.

6.2.5 HET -6A. This line provides analog power at -6 V, used in HK ADC. Its maximum current draw during the steady-state operation shall not exceed 1 mA.

6.2.6 HET +2.6D. This line provides digital power at +2.6 V, primarily used for core supply of Actel gate array. Its maximum current draw during the steady-state operation shall not exceed 20 mA.

6.2.7 HET +3.4D. This line provides digital power at +3.4 V, primarily used for I/O supply of Actel gate array, SRAM and 32 MHz clock oscillator in HET. Its maximum current draw during the steady-state operation shall not exceed 55 mA.

6.2.8 HET +5.1D. This line provides digital power at +5.1 V, primarily used in the interface circuits: HC14 and HCT240. Its maximum current draw during the steady-state operation shall not exceed 0.1 mA.

6.3 SSD Bias Supply Protocol. SSD Bias Supply output listed below shall be shared between LET L3 and HET H1-6 detectors, supplied from a single +300 V regulator.

6.4 Signal Description.

6.4.1 HET BIAS. Selectable by means of passive components, this signal shall be set for flight to a value in the range of 50-250 V that is agreeable to both HET and LET. Its current limit shall be set to 280 μA at a 10 % droop from the selected nominal voltage. The limit would allow for all of the HET detectors to draw the maximum leakage at the end of the life and at 40 ºC, including one short-circuited detector (the worst case, i.e., H1), which could draw 10 times its leakage under the same conditions.

7. Heaters

HET operational and survival heater power is supplied by the STEREO spacecraft, with SEP_Central only providing a connection between the spacecraft and the HET instrument. HET shall monitor its thermal environment and control its operational heater accordingly. SEP Thermal Engineer shall actively participate in selection of the operational and survival heater type and their location in the HET instrument.

7.1 Protocol. SEP_Central and HET shall route the signals listed below in a way that traces are kept close together on the harness and PCBs to minimize the introduction of electric noise. These signals carry a nominal +28 VDC voltage fed from S/C buss capable of supplying 28 +7/-6 VDC. Per RFA 62 Response to STEREO S/C PDR, in order to prevent this large voltage variation (+22 V to +35 V) from affecting the design peak power of the heaters, the following design guidelines shall be followed:

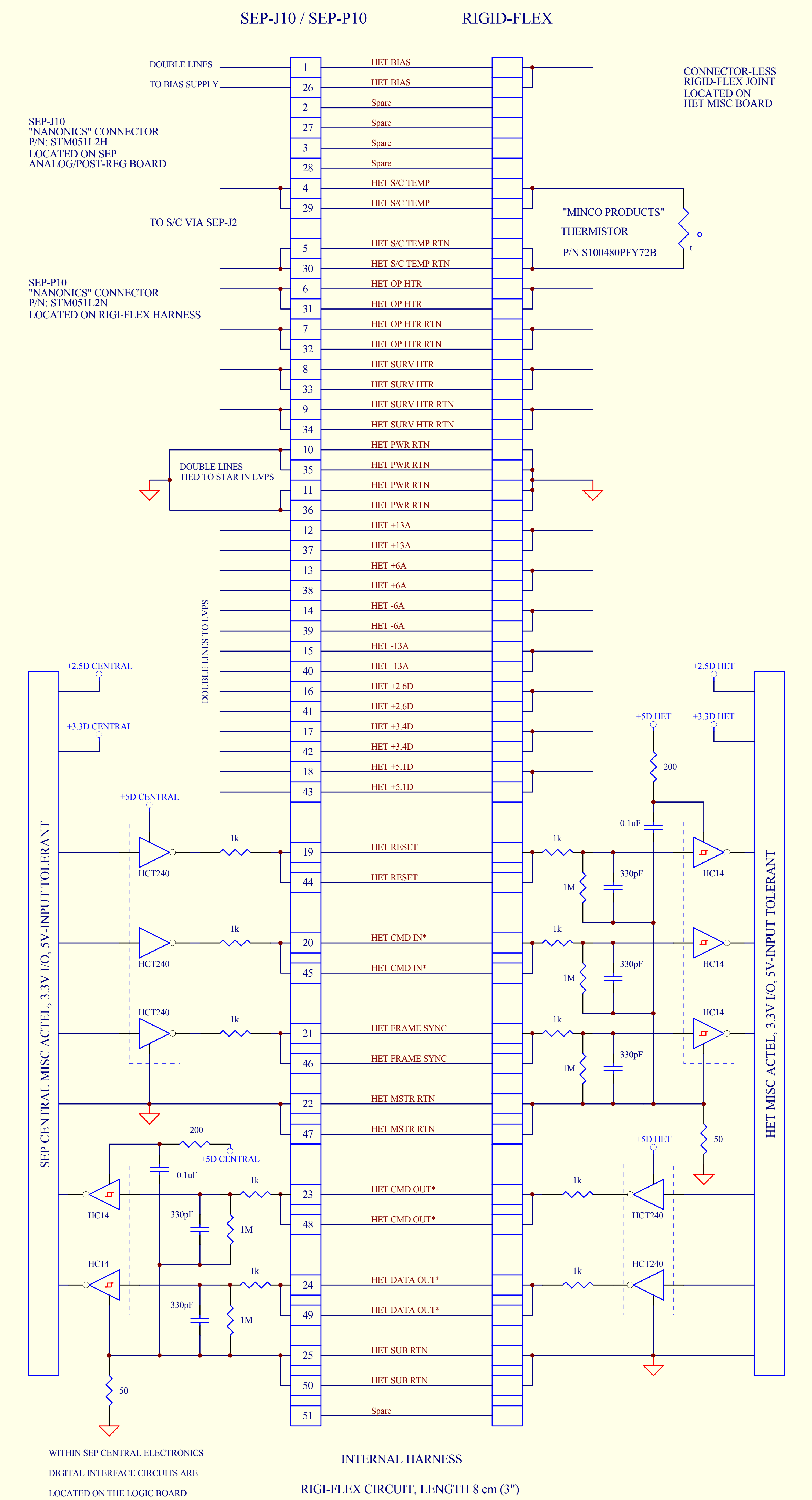
7.1.1 HET operational heater shall be sized for a 75% duty cycle at 30.5 V.

7.1.2 HET survival heater shall be sized for a 100% duty cycle at 25 V.

7.2 Signal Description.

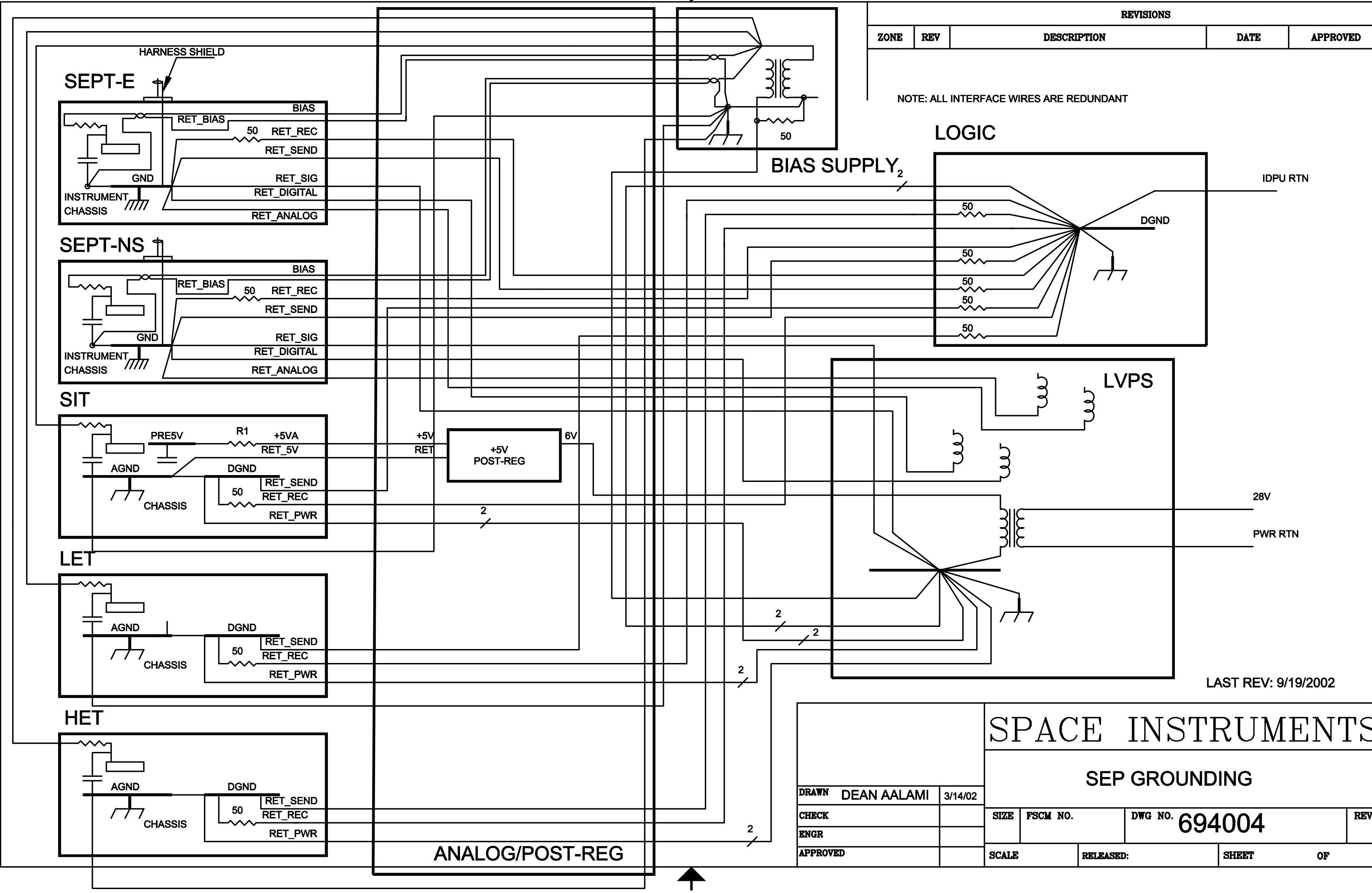
7.2.1 HET OP HTR and HET OP HTR RTN. These are a pair of signals that supply nominal +28 VDC power to the HET operational heater when SEP power is turned on. They are fed from the same S/C power buss as the main SEP power. HET OP HTR signal shall be pulsed on and off by a heater switch located inside HET and controlled by the HET MISC.

7.2.2 HET SURV HTR and HET SURV HTR RTN. These are a pair of signals that supply nominal +28 VDC power to the HET survival heater when SEP power is turned off. They are fed from a separate S/C power buss that turns on when the main SEP power is turned off. A thermostat in the HET instrument shall control HET SURV HTR signal whenever SEP is powered off.



LEGEND
LOCAL CHASSIS, I.E., SIGNAL GROUND

Title HET-SEP_Central I/F Schematic			*California Institute of Technology* *Space Radiation Laboratory* *1201 E. California BL* *MC 220-47* *Pasadena, CA 91125*
Size:	Number:	Revision:	
Date: 9-Oct-2002		Sheet 1 of 1	
File: C:\Protel\Stereo\ICD\SEP ICD.Ddb - Documents\HET			



REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED

NOTE: ALL INTERFACE WIRES ARE REDUNDANT

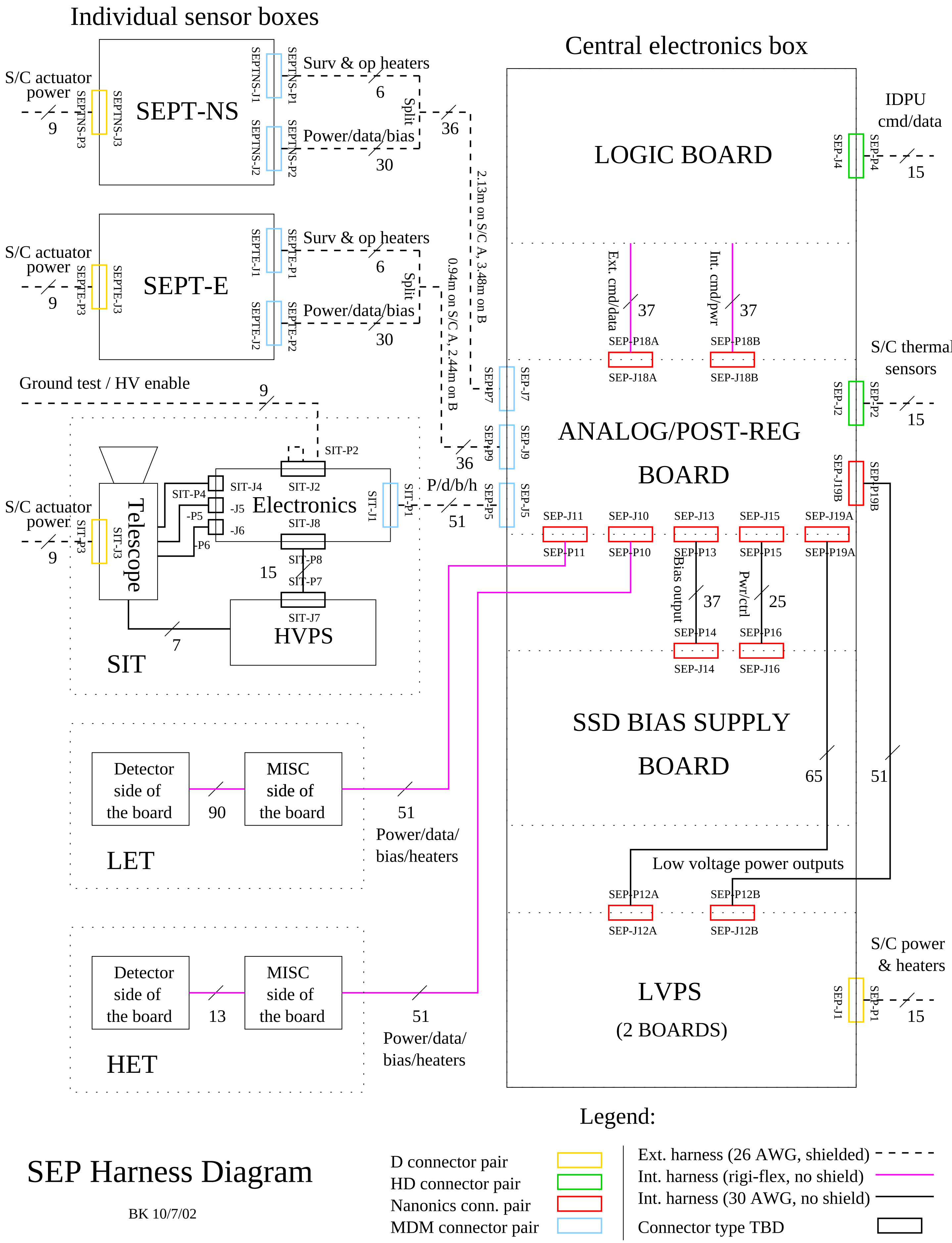
LAST REV: 9/19/2002

DRAWN	DEAN AALAMI	3/14/02
CHECK		
ENGR		
APPROVED		

SPACE INSTRUMENTS

SEP GROUNDING

SIZE	FSCM NO.	DWG NO. 694004	REV
SCALE	RELEASED:	SHEET	OF



SEP Harness Diagram

BK 10/7/02

TELEMETRY PACKET

Primary Packet Header								Secondary Packet Header		App Data
Version Number	Packet Identification Field				Packet Sequence Control		Packet Data Length	Spacecraft Time		
	Type Indicator	Secondary Header Flag	Application Process ID: Subsystem Identifier	Application Process ID: Data Format ID	Grouping Flag	Source Sequence Count		Seconds since Epoch	Subsecs since Epoch	
"00"	"0"	"1"	0 C&DH 2 G&C 4 IMPACT 6 PLASTIC 8 SECCHI 10 SWAVES	See ApID table	01=First 00=Cont 10=Last 11=no grp	decimal 0 to 16,383	# bytes minus 1, decimal 265	Rollover in 2094	4 msec count	
3 bits	1 bits	1 bits	4 bits	7 bits	2 bits	14 bits	16 bits	32 bits	8 bits	2088 bits
48 bits								40 bits		261 bytes
2176 bits / 272 bytes										

Figure 11. CCSDS Telemetry Packet Data Structure Diagram

Table 15. CCSDS Telemetry Packet Format

CCSDS Telemetry Packet				
Contents	Size (bits)	Size (bytes)	Type	Units/Range
PRIMARY PACKET HEADER				
Version Number	3	0.375	Binary	"00"
PACKET IDENTIFICATION FIELD				
Type Indicator	1	0.125	Binary	"0" designates a telemetry packet
Secondary Header Flag	1	0.125	Binary	0 = No secondary header 1 = Secondary Header Present
APPLICATION PROCESS IDENTIFIER				
Subsystem ID	4	0.500	Binary	0 = 0000 = C&DH 2 = 0010 = G&C 4 = 0100 = IMPACT 6 = 0110 = PLASTIC 8 = 1000 = SECCHI 10 = 1010 = SWAVES
Data Format ID	7	0.875	Binary	See ApID table
PACKET SEQUENCE CONTROL				
Grouping Flag	2	0.250	Binary	01 = First Packet 00 = Cont. Packet 10 = Last Packet 11 = No grouping
Source Sequence Count	14	1.750	Binary	Decimal range = 0 to 16,383 To ensure delivery order, increment this counter
Packet Data Length	16	2.000	Binary	Number of bytes in Secondary Header Fields + Application Data Field **minus 1, For STEREO = (261 + 5) - 1 = decimal 265 = binary 00000000 10001001**
SECONDARY PACKET HEADER				
SPACECRAFT TIME				
Seconds since Epoch	32	4.000	Binary	Seconds since Epoch Jan 01, 1958 00:00:00 UTC, Rollover in 2094
Subseconds	8	1.000	Binary	Subseconds (1/256)
Application Data	2088	261	Variable	Telemetry application data
TOTAL SIZE (bits & BYTES)	**2176**	**272**		