SEPT Housing

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Abstract

This note describes the mechanical housings of the *Solar Electron Proton Telescope* (SEPT) for IMPACT on the NASA space probes STEREO, for the purpose of a structural analysis to verify environmental specifications required for launch.

This document is available electronically at:

http://www.ieap.uni-kiel.de/
space/project/stereo/sept/notes/texts/housing.pdf

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1 Description of the Housing

The SEPT consists of two identical modules which are mounted at different locations on the spacecraft. One module (SEPT-E) detects particles in the ecliptic in the direction of the solar magnetic field, the other (SEPT-NS) perpendicular to the ecliptic.

Each module is composed of two parts: the housing of the sensor on the top, and the *electronics box* (E-box) on the bottom. The sensor housing is mounted on top of the E-box with four screws (M4). The sensor is electrically and thermally connected to the E-box.

The E-box is mounted on the spacecraft with four screws size ANSI 8. The E-box mounting provides electrical and thermal insulation from the spacecraft. While SEPT-E is mounted directly to the spacecraft platform, SEPT-NS will be mounted on a bracket, as shown if Fig. 18. The bracket weighs 270 g. The mechanical analysis for SEPT-NS shall include this bracket.

Fig. 1 shows the instrument from the front and from the side. Fig. 17 on page 15 indicates the mounting positions of the SEPT modules on the spacecraft. See Table 1 on page 19 for a weight breakdown of the SEPT modules.

1.1 Materials

The housing is made of aluminum (AA 7075, DIN 3.4365), with a few exceptions:

- The sensor doors are made from titanium, for its low thermal conductance.
- The pinpuller rods are made of bronze, to avoid friction in the door mechanism.
- All screws, washers, etc., are stainless steel.

The material thickness is 1 mm except where noted otherwise.

1.2 Electronics Box

The E-box is a rectangular box with removable top and bottom covers. See Figs. 2 to 4.

The body of the box is, like all other parts of the housing, machined from a solid block of aluminum (no welding).

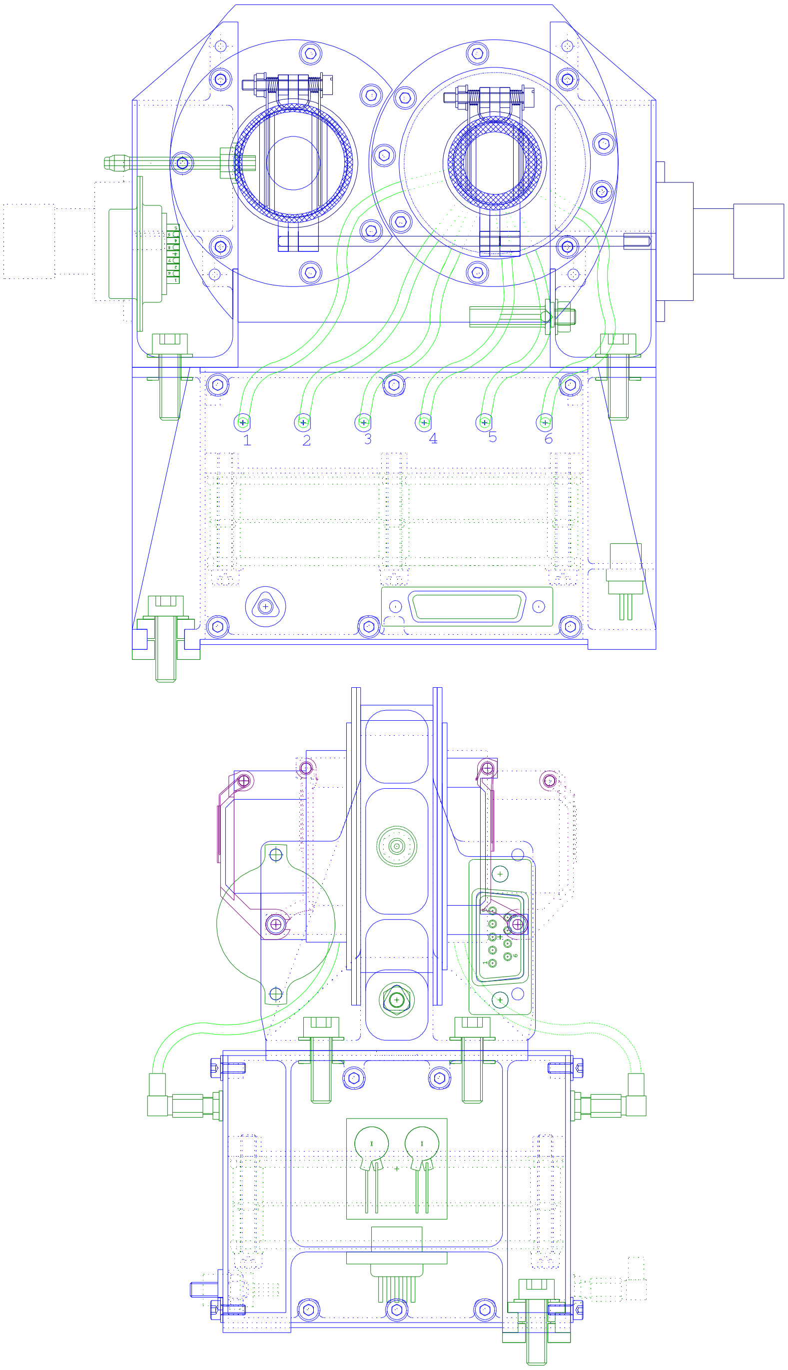

Figure 1: SEPT Housing overview.

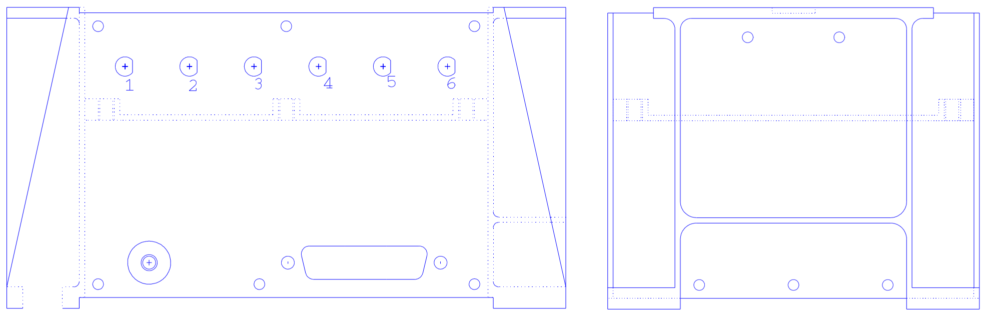

Figure 2: The body of the electronics box.

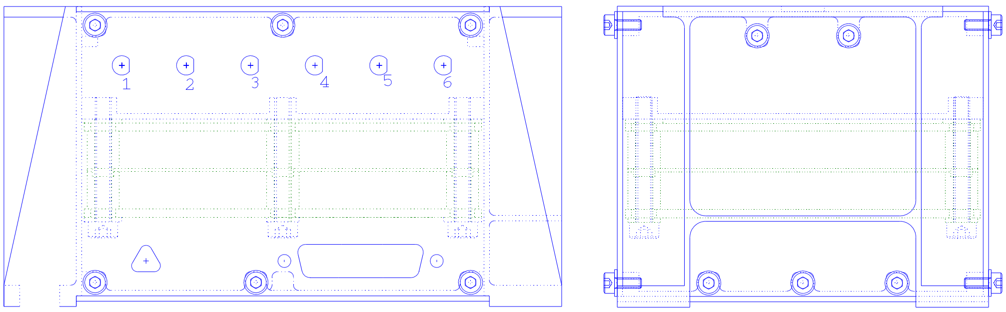

Figure 3: The electronics box with covers.

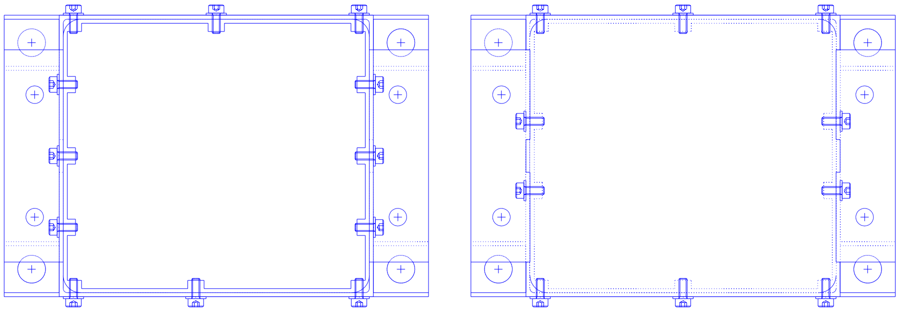

Figure 4: The electronics box with bottom (left) and top (right) covers.

The top (bottom) covers are are fixed with ten (twelve) stainless steel screws (M2) from the sides through holes in the body, into threads which are cut into extension on the covers.

Two *Printed Circuit Boards* (PCB) with an EMI shield in between are mounted inside the E-box. The PCBs and the EMI shield are assembled outside the box, inserted from the bottom, and screwed with six screws (M3) onto threaded holes that are part of the E-box body. The connectors for the electronics are pushed from the inside through their respective holes in the E-box body, and fixed with screws.

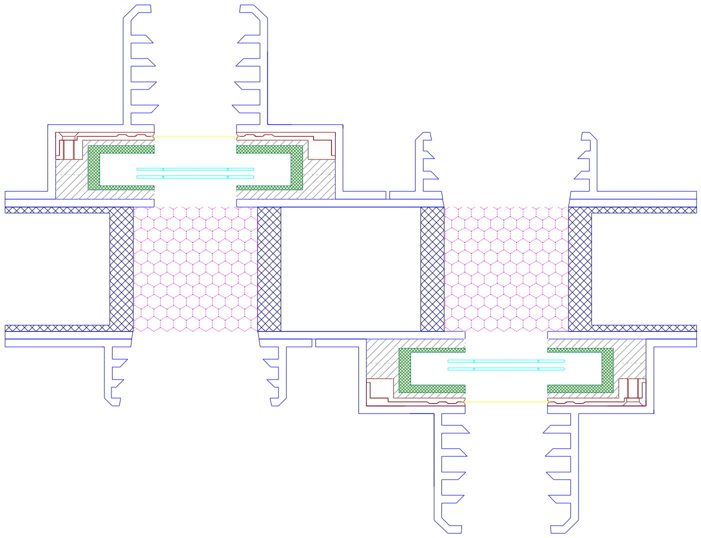

Figure 5: Sensor top view. Silicon detectors (cyan), magnets (magenta), foil (yellow), foil carrier ring (brown), detector housing (green), Delrin (gray).

1.3 Sensor Housing

The sensor (Fig. 5) has four apertures for incident particles, looking in two opposite directions. Each pair of opposite views share a pair of silicon detectors. The particles either have to pass through a thin Parylene foil or through a magnetic field. The foil stops slow protons, and the magnetic field filters electrons.

1.3.1 Magnet Assembly

The sensor includes four NdFeB Magnets, size $16 \times 16 \times 8\,\mathrm{mm}^3$. The magnets are glued to two yokes, made of Vacoflux 50. The magnet-yoke assemblies are

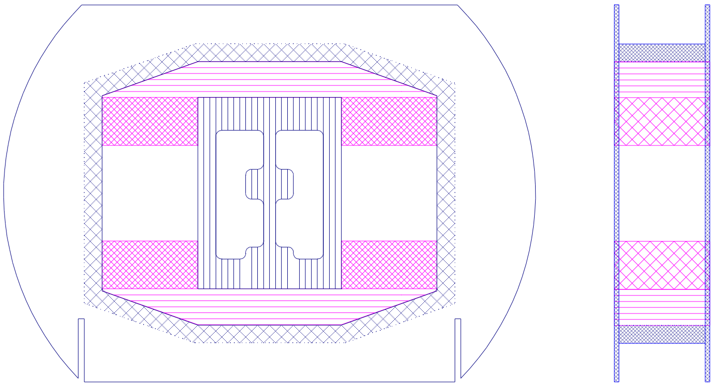

Figure 6: Magnet assembly. Magnets and yokes (magenta), frame and magnet support (dark blue).

held apart by a magnet support, which also serves to enclose the particle's path to the detectors. The complete magnet assembly is inserted into the *sensor frame*, which is 3 mm thick, surrounding the magnet assembly, and which extends with 0.8 mm thick sheets at both sides. See Fig. 6.

The mass of the magnets is 15.6 g each (density 7.63 g/cm^3), and each yoke's mass is 31.2 g (density 8.12 g/cm^3).

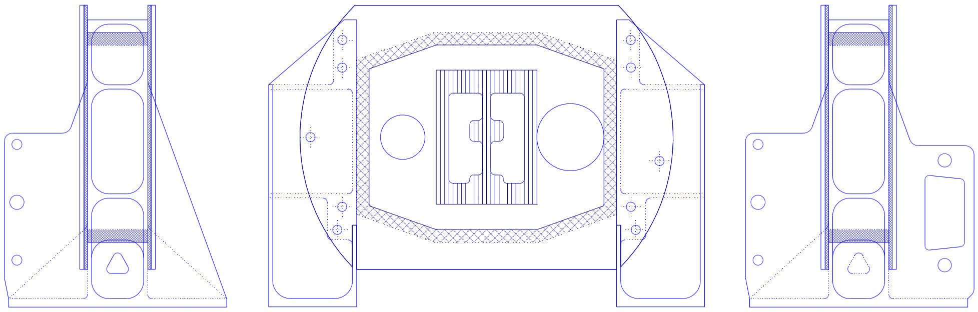

Figure 7: Sensor side support. The side supports slide from below between the extensions of the sensor frame, and the inner support wings of the side supports slide into the slits of the frame and its covers.

1.3.2 Sensor Side Support

The magnet assembly will be covered on both sides by frame covers, with round holes for the particle paths. Two *side supports* will slide between the extensions of the sensor frame. See Figs. 7 and 8. The side support's inner

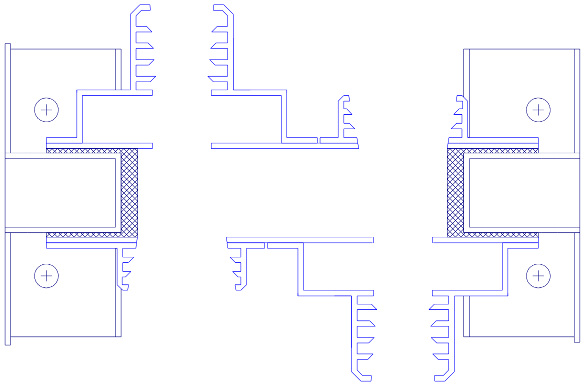

Figure 8: Sensor side supports and collimator top view.

enforcement wings slide into slits of the sensor frame and cover. The outer support wings also serve to mount pinpullers and a connector.

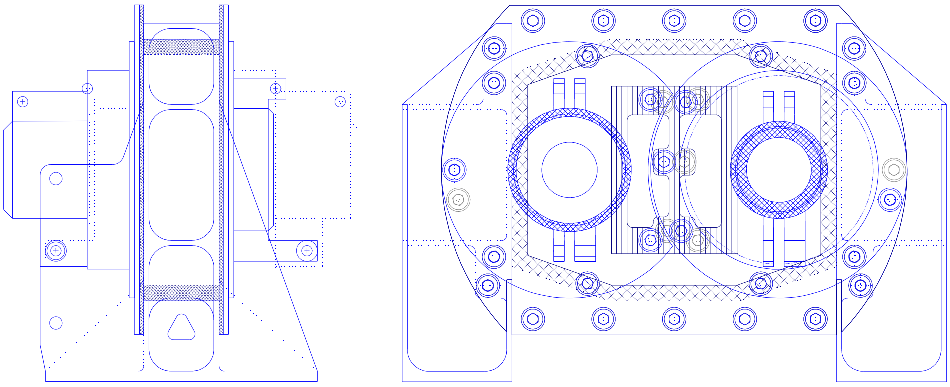

Figure 9: Collimator assembly. The positions of the screws are indicated on the front view. The grayed screw positions are for the reverse side. Some positions are shared.

1.3.3 Collimators

The collimators of the telescope will be mounted on top of the frame covers. Two of these collimator structures also serve as the housing for the detectors and foil assemblies. The hinges for the sensor doors and their release mechanism are part of the collimator structure. See Fig. 9.

1.3.4 Screws

The sensor is held together by stainless steel screws (M2). The right side of Fig. 9 shows the positions of the screws:

Five screws on in the center on each side hold the collimators and frame covers and screw into threads in the magnet support.

Four screws on each side hold the collimators and frame covers and screw into threads cut into the frame.

Four long screws go through the collimators and frame covers, all the way through the side supports and are tightened with nuts on the other side. Four more screws go likewise all the way through, but not through the collimator flanges.

Twenty short screws and nuts, five on the top and bottom of each side, hold together the frame and frame covers.

Four screws and nuts, one each on the left and right of each side, fix a collimator, frame cover, frame, and side support.

1.3.5 Detector Assembly

The silicon detector pairs are assembled inside separate housings. The foils are mounted in aluminum rings. A foil carrier ring and a detector housing is mounted inside a collimator. The detector housing is surrounded by Delrin rings, for electrical isolation. See Fig. 5.

1.3.6 The Sensor Doors

The four sensor openings are covered with doors, which are to be opened only after the spacecraft reached a stable orbit, to prevent direct sunlight to shine on the sensitive detectors and magnets during maneuvers. These doors are not reclosable. The opening mechanism is activated with two pinpullers, opening two doors each. The doors are not sealed.

Fig. 10 shows a side view of the doors in closed and open position, and Fig. 11 shows the front view. The pinpuller, when activated, pulls a rod by a few millimeters and releases the door locks. The doors open by the force of springs.

The left door opens when the rod slips out of its lock, but the right door opens when an extension of the rod slips out of an extended hole, so that the rod can slip through an opening in the lock. The rod is guided by holes that are part of the collimator structures. These guides are designed such that the (extension of) the rod does not slip out even when the pinpuller is fully activated.

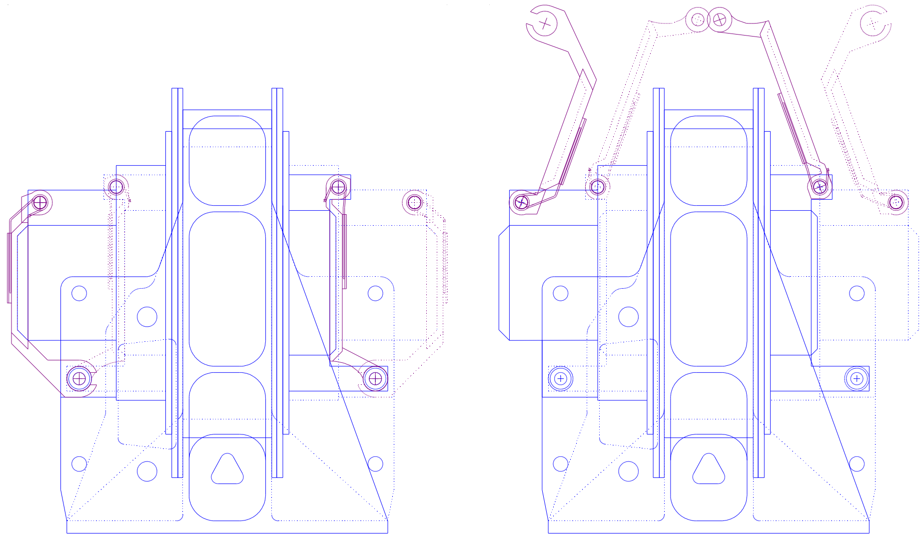

Figure 10: Sensor doors side view. Left: doors in closed position, right: doors in open position.

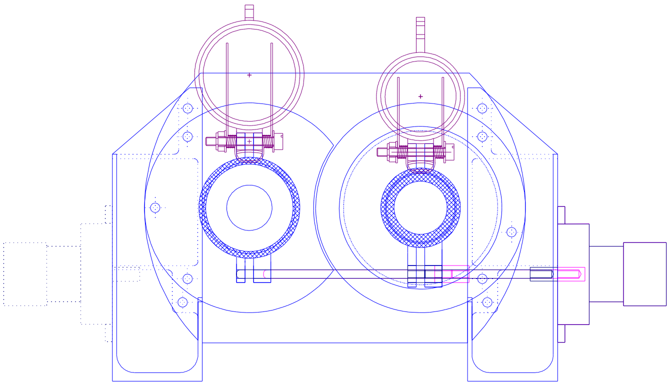

Figure 11: Sensor doors front view, with the doors opened. The pinpuller rod is drawn in both the idle (dark blue) and activated (pink) position.

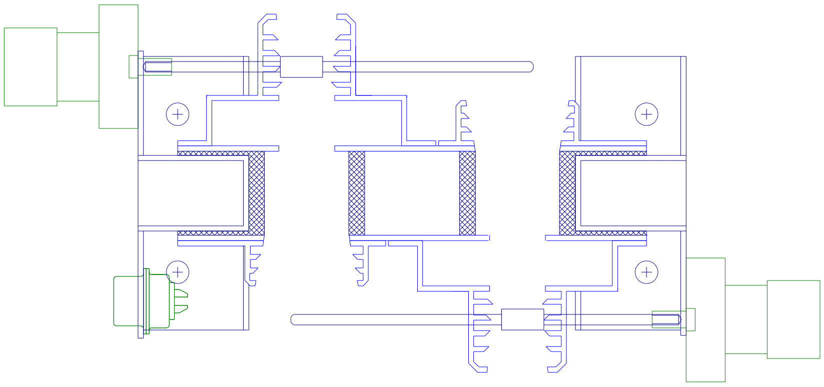

Figure 12: Pinpuller mounting top view. Also shown is the connector for the supply of the pinpuller activation current.

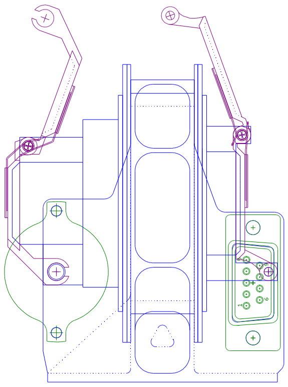

Figure 13: Pinpuller mounting side view. Only the near half of the sensor is shown. The sensor doors are drawn both opened and closed.

The doors are made of titanium, while the rod is made of bronze. The hinges and guides are part of the collimators which are made of aluminum.

1.4 Connectors and Miscellaneous Attachments

Various objects are attached to the housing.

1.4.1 Pinpullers

The sensor doors are activated by two pinpullers from TiNi Aerospace, Inc., Model P5-403-10S, which are attached with two screws to outer wings of the side supports. These pinpullers weigh 15 g each.

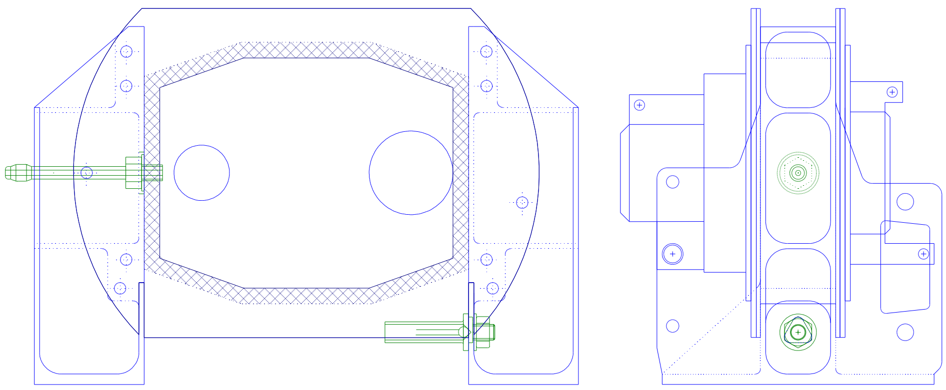

Figure 14: Purge nipple and thermistor (green). The purge nipple is the upper left and the thermistor is the lower right part in green.

The axis of the pinpuller comes with an internal thread (M2) where the bronze rod is screwed into. The rod diameter is 2 mm. The extension of the shaft that locks the right door is 8 mm long and the extended diameter is 4 mm. See Figs. 12 and 13.

The pinpullers are activated electrically from the spacecraft. The connection is made via a 9-pin subminiature D-type connector which is screwed to an outer wing of a side support. Such a connector weighs 6 g.

1.4.2 Purge Nipple

To purge the sensor with nitrogen gas before launch there is a *purge nipple* screwed into the sensor frame from the side. The side support has a hole at that position. The design of the purge nipple is not yet final, because a flow limiter needs to be incorporated. See Fig. 14.

1.4.3 Detector Signals

The detector signals are routed through twelve coax cables type RG 178, six for each detector pair, which leave the detector housing to the side, over an angle of 135°. The cables attach to the E-box via SSMC type connectors. Such a connector pair weighs 2.5 g.

The cable will need to be fixed to the E-box cover somehow. This part of the design is not yet finished.

Figs. 15 and 16 show the positions of these cables and various other connectors.

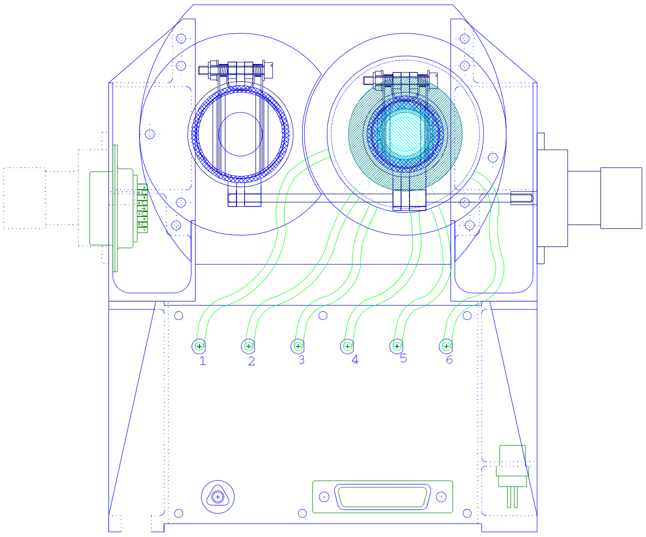

Figure 15: Cables and connectors front view. The detector signal cables are drawn in light green. The connector on the right between the support wings of the E-box supplies the thermal hardware. The MDM connector on the front is the link to SEP central. To its left is the grounding stud.

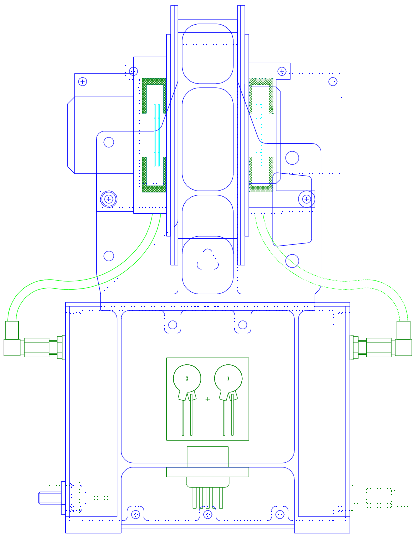

Figure 16: Cables and connectors side view. The detector signal cables are shown with connectors. Also shown on the lower right is the connector for the thermistor. In the center, on the E-box sidewall is shown the thermostats for the survival heater, and the connector for the thermal hardware. At the lower left are the SEP connector and the grounding stud.

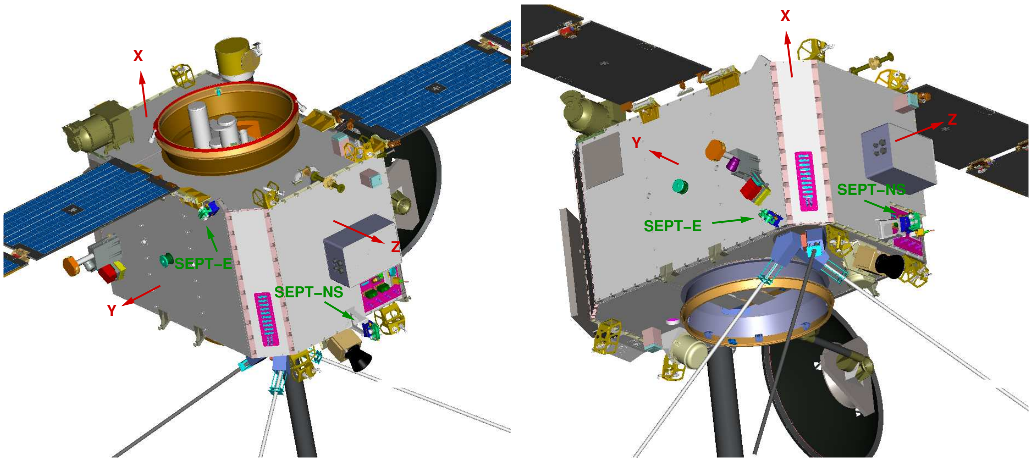

Figure 17: STEREO-B (behind, left) and STEREO-A (ahead, right).

1.4.4 SEP Connection

The electronics upstream connection of the E-box to *SEP central* goes through a 31-pin MDM connector.

1.4.5 Thermistor

A thermistor is required to measure the temperature of the sensor, close to the silicon detectors. The thermistor is glued into an stainless steel cylinder, which is attached to a side support from the inner side below the sensor. The connection is made with a coax cable from the inner end of the thermistor to a connector on the back side of E-box, opposite to the SEP connector. Cable and connector are the same type as for the detector signals. See Fig. 14.

1.4.6 Thermal Hardware

Survival and operational heaters will be attached on the outside to the bottom of the E-box. Two thermostats for the survival heater will be glued to the sidewall of the E-box. The electrical connections to the spacecraft will use a 9-pin MDM connector which is attached to the E-box near the thermostats. See Figs. 15 and 16.

1.4.7 Ground Stud

A stainless steel grounding stud is screwed to the front of the E-box next to the SEP connector. See Figs. 15 and 16.

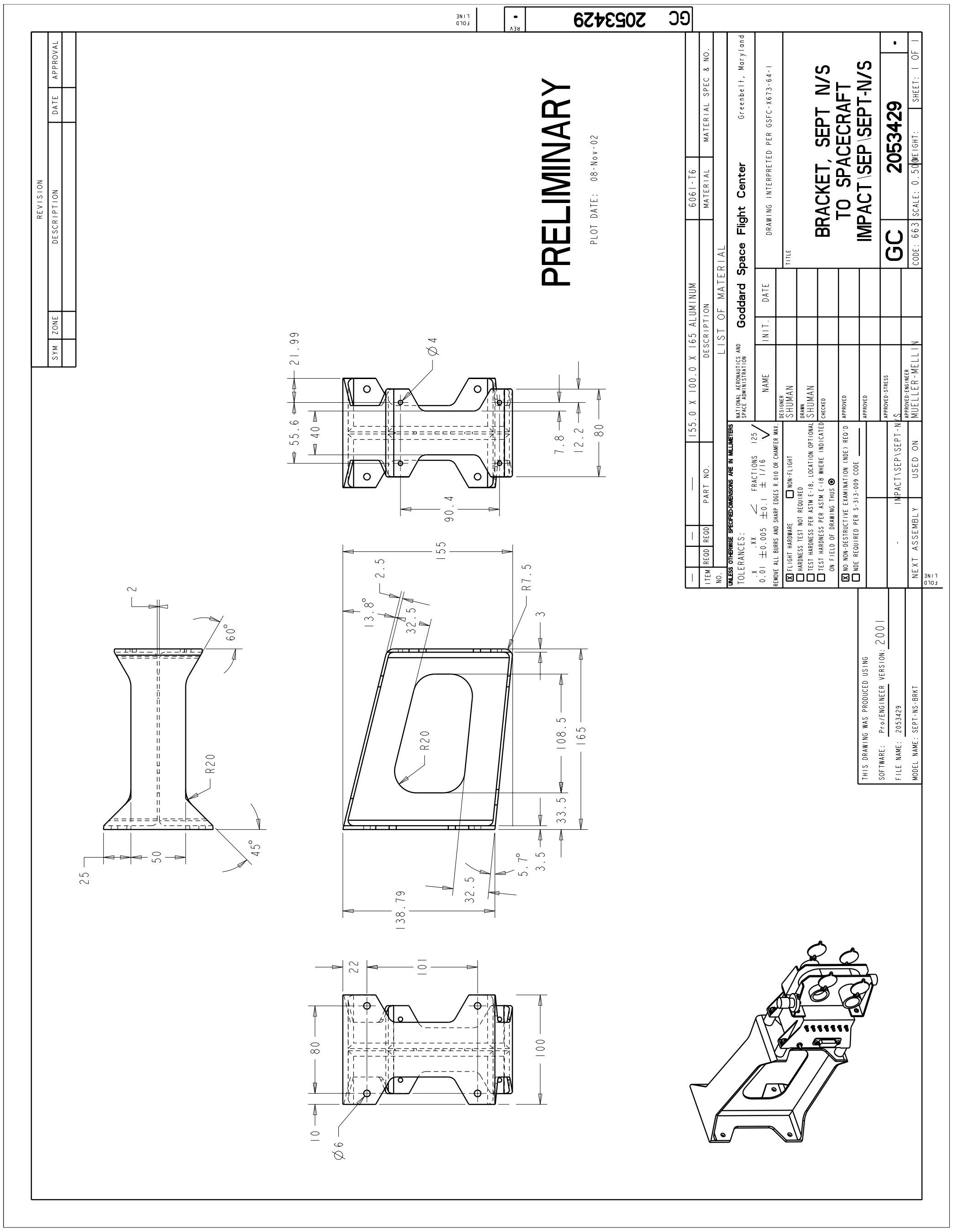

Figure 18: SEPT-NS mounting bracket design drawing.

2 Vibration Levels

These are quoted from the environmental specifications for instruments on the STEREO spacecraft.

SEPT-E is mounted to the spacecraft Y-axis panel, SEPT-NS is mounted to the spacecraft Z-axis pannel. The SEPT mounting plane contains the thrust axis, the spacecraft X-axis (Fig. 17).

2.1 Instrument Design Load Factors

> *The instrument shall be designed to the limit loads (maximum expected loads) multiplied by the appropriate factor of safety. The design loads shall be applied separately in three orthogonal axes to the instrument center of gravity.*

See Tables 2 and 3 for the factors.

2.1.1 Margin of Safety for Instruments

> *Instrument strength analysis must show a positive margin of safety (MS). Margins of safety for yield strength (MSY) and ultimate strength (MSU) are defined as follows:*

$$\mathrm{MSY} = \frac{\text{Material Yield Strength}}{1.3 \times \text{Applied Stress}} - 1 \quad > \quad 0$$

$$\mathrm{MSU} = \frac{\text{Material Ultimate Strength}}{1.4 \times \text{Applied Stress}} - 1 \quad > \quad 0$$

2.2 Instrument Stiffness

> *Instruments shall be designed such that the primary vibration modes are above* 50 Hz.

2.3 Instrument Sine Sweep Vibration Tests

> *Instruments shall be subjected to the following sinusoidal vibration levels. These shall be applied in each of three orthogonal axes.*

See Table 4 for the levels.

2.4 Random Vibration Levels

> *All instruments shall be subjected to the following random vibration levels. These shall be applied to each of three orthogonal axes, one of which is parallel to the thrust axis.*

See Table 5 for the levels.

Table 1: SEPT weight breakdown

E-Box			240.1 g
housing		100.1 g	
box	60.5 g		
covers	35.6 g		
screws	4.0 g		
electronics		132.0 g	
PCBs	88.0 g		
EMI shield	8.0 g		
connectors	13.0 g		
internal cables	18.0 g		
screws	5.0 g		
thermal hardware		8.0 g	
sensor			425.4 g
housing		193.0 g	
frame	33.5 g		
frame covers	24.8 g		
magnet support	20.0 g		
side supports	50.8 g		
collimators	30.5 g		
doors	17.2 g		
screws	16.2 g		
magnets		130.0 g	
detector system		48.6 g	
pinpuller and rod		37.6 g	
miscellaneous		16.2 g	
SEPT total weight			665.5 g

Table 2: Quasi static Load Factors

Component Weight	**Limit Load**
$< 4.5\,\mathrm{kg}$	$30\,\mathrm{g}$

Table 3: Factors of Safety for Instruments

	Design
Material Yield	$\geq 1.3 \times$ limit load factors
Material Ultimate	$\geq 1.4 \times$ limit load factors
Buckling	$> 2.0 \times$ limit load factors
Composites	$> 2.0 \times$ limit load factors
	Vibration Test
Sine Vibration	$1.4 \times$ max expected level
Random Vibration	max expected level $+ 3\,\mathrm{dB}$

Table 4: Sine Sweep Levels for Instruments Weighing Less than or Equal to 45 kg. Rate = 4 octaves/min. Above 50 Hz, component response may be limited to peak input level.

Thrust Axis (X)

Frequency	Acceleration
5 to 7.4 Hz	0.5 in (double amplitude)
7.4 to 23 Hz	1.4 g
25 to 27 Hz	16.0 g
29 to 100 Hz	1.4 g

Lateral Axes (Y,Z)

Frequency	Acceleration
5 to 6.3 Hz	0.5 in (double amplitude)
6.3 to 19 Hz	1.0 g
21 to 23 Hz	12.0 g
25 to 100 Hz	1.0 g

Table 5: Random Vibration Levels for Instruments Mounted Directly to Spacecraft Panel and Weighing Less than or Equal to 22.7 kg

Perpendicular to Mounting Panel

Frequency	PSD Level
20 Hz	0.0063 g^2/Hz
20 to 80 Hz	+6 dB/oct
80 to 800 Hz	0.1 g^2/Hz
800 to 2000 Hz	−9 dB/oct
2000 Hz	0.0065 g^2/Hz

Overall Amplitude = 10.4 g rms
Duration = 60 seconds

Parallel to Mounting Panel

Frequency	PSD Level
20 Hz	0.0031 g^2/Hz
20 to 80 Hz	+6 dB/oct
80 to 800 Hz	0.05 g^2/Hz
800 to 2000 Hz	−9 dB/oct
2000 Hz	0.0032 g^2/Hz

Overall Amplitude = 7.4 g rms
Duration = 60 seconds