C.3.0 Solar Energetic Particles (SEP) Subsystem

The Solar Energetic Particles (SEP) subsystem selected for STEREO/IMPACT consists of the Solar Electron Proton Telescopes (SEPT), the Suprathermal Ion Telescope (SIT), the Low Energy Telescope (LET), and the High Energy Telescope (HET). This section begins with an overview of the SEP subsystem, followed by detailed descriptions of SEPT, SIT, LET and HET.

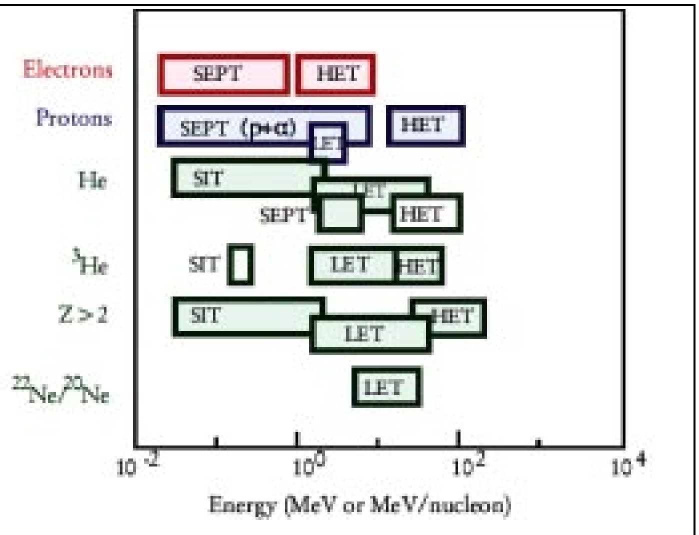

Figure C.3-1. Energy range over which the four SEP sensors can measure various species.

The SEP subsystem is designed to measure the intensities of energetic particles from solar flares and from Coronal Mass Ejection (CME) driven shocks over a wide range of energies, intensities and particle types. The charge and energy ranges covered are illustrated in Figure C.3-1. In addition to protons, Helium and heavier ions, electrons are detected by SEPT and HET. HET observes the most penetrating particles, the ones which are most relevant for astronaut safety. The SEPT telescopes are the only ones to include magnets.

Subsequent to the selection of IMPACT for STEREO, our Japanese Co-Investigator from Waseda University failed to get funding approval for participation in STEREO. We have separately submitted two proposals to the STEREO Project Office: one proposal to completely replace the Japanese effort within the group of US SEP Co-Investigators and a second proposal which outlines the impact of (1) no cost increase and (2) a compromise between fully replacing the Japanese effort and no cost increase. The second proposal is contained in Appendix F. It is our understanding that no decision will be made on resolving this issue until after the Phase A report has been submitted. For the purposes of Phase A, therefore, we will concentrate on a plan which implements the suggested compromise since the zero cost option produces a substantial loss of science and full implementation may be regarded as too expensive. Selection of a different option is in no way compromised by this approach but the decision must be made as soon as possible. The primary effect is that the compromise HET weighs more (~700 g) than the original HET (~330 g).

The SEP telescopes were originally proposed to be mounted on a single box containing electronics for each telescope as well as a common electronics system. The common electronics includes a low voltage power supply, a bias voltage supply, and a microprocessor which interfaces with the IMPACT Instrument Data Processing Unit (IDPU). The IDPU acts as a bent pipe for

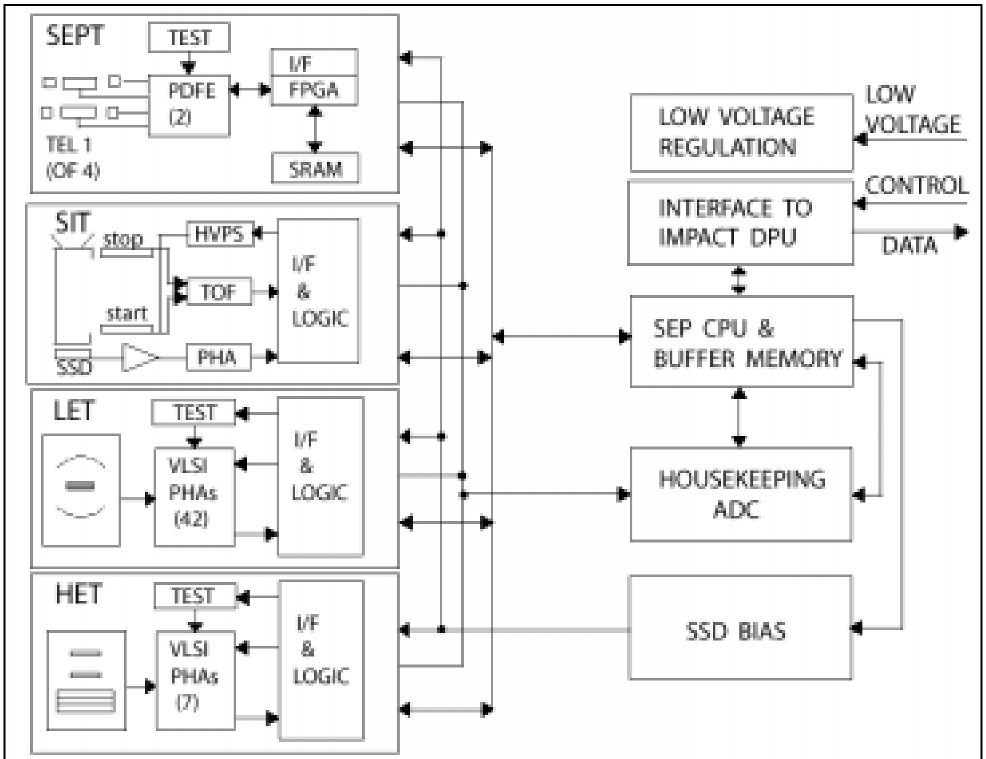

Figure C.3-2. Block diagram of the electronics for the overall SEP subsystem.

Telescope	**Nominal**			**Current**			**Impingements**	
	Phi	Theta	FOV	Phi	Theta	FOV	**Forward (N)**	**Backward (S)**
SEPT- N/S	-	90	60, 70	-	90	60, *60*	***Corner of Spacecraft Lower Deck***	***Corner of Spacecraft Lower Deck***
SEPT-ECLIPTIC	45	0	60, 70	45	*5*	60, *60*	None	None
SIT	60	0	44 x 17	60	0	44 x 17	None	N/A
LET	45	0	133 x 30	*54*	0	133 x 30	None	***Spacecraft Body***
HET	45	0	47.5	45	0	47.5	None	None

Table C.3-1. STEREO/IMPACT/SEP Fields of view for leading spacecraft (degrees). Note: Phi = angle between spacecraft-sun line and the field of view central axis projected onto the ecliptic plane. Theta = angle between field of view central axis and ecliptic plane. Impingements with SWAVES antennas have been ignored.

spacecraft commands to the SEP subsystem and for data output from the SEP subsystem to be telemetered to the ground. A block diagram of the electronics for the overall SEP subsystem is shown in Figure C.3-2. General SEP properties, including fields of view, beacon data content, and resource requirements, are summarized below. The SEP common electronics are described in section C.3.5.

C.3.0.1 Fields of View

The following discussion of the SEP fields of view is based upon the spacecraft design presented at the STEREO System Requirements Review. This design is currently in flux, so the analysis presented here is likely to undergo future revision.

In the original proposal it had been found possible to bolt the SEP box directly to the spacecraft and clear all the SEP telescope view angles. During Phase A, however, the spacecraft design has been completely revamped and this is no longer possible. Due to the fact that the SEPT, LET and HET telescopes have fairly large, double-ended fields of view, clearing these fields of view has not been an easy problem to solve. Significant changes have been made to the SEP subsystem configuration in order to find a solution in which all the SEP telescope fields of view are (mostly) clear. These changes are listed in Tables C.3-1 (leading spacecraft) and C.3-2 (trailing spacecraft). For example, the SEPTs included opening angles of 70^{o,} which have now been reduced to 60^{o}. The nominal look directions have also been relaxed by as much as 9^{o}. There are also pending requests to the spacecraft design for additional modifications, mentioned below, which will enable complete clearance of the SEP fields of view.

The approach taken has been to minimize differences between the two STEREO spacecraft and absorb as much of the solution into the SEP design as possible. This of course increases the cost and complexity of SEP somewhat, but simplifies the two spacecraft. The SEP subsystem has now been divided into two parts: the SEPT North-South telescopes (SEPT-NS) and the rest of the SEP subsystem (main SEP box). Identical SEPT North-South telescopes are located in the same locations on both the leading and trailing STEREO spacecraft (see Figure C.3-3). The SEPT North-South telescopes are also identical to the in-ecliptic SEPT telescopes mounted on the main SEP boxes on the leading and trailing STEREO spacecraft. The main SEP boxes, however, are somewhat different on the two spacecraft and they are also mounted in different locations. This was necessary in order to clear the corresponding view angles and to maintain fields of view predominantly along the mean interplanetary magnetic field direction (Parker spiral). The two different positions are indicated in Figure C.3-4. The SEP positioned underneath the Plastic instrument at the top right of the spacecraft body in Figure C.3-4 corresponds to the trailing spacecraft. The other SEP depicted in Figure C.3-4, near the top left corner of the spacecraft body in Figure C.3-4, corresponds to the leading spacecraft. The North-South SEPT can be seen outboard of the spacecraft at center left. In the original design, the SEP box derived structural support by being bolted directly to the spacecraft body, whereas now neither the SEPT North-

Telescope	**Nominal**			**Current**			**Impingements**	
	Phi	Theta	FOV	Phi	Theta	FOV	**Forward (N)**	**Backward (S)**
SEPT- N/S	-	90	60, 70	-	90	60, *60*	***Corner of Spacecraft Lower Deck***	***Corner of Spacecraft Lower Deck***
SEPT-ECLIPTIC	45	0	60, 70	*43*	*5*	60, *60*	None	None
SIT	60	0	44 x 17	60	0	44 x 17	None	N/A
LET	45	0	133 x 30	*52.5*	0	133 x 30	***Plastic***	***Spacecraft Body***
HET	45	0	47.5	45	0	47.5	None	None

Table C.3-2. STEREO/IMPACT/SEP Fields of view for trailing spacecraft (degrees).

South telescopes nor the main SEP boxes are so mounted. With the current design both parts of SEP are mounted outboard of the spacecraft. Brackets are therefore necessary for support against launch loads and vibration. Preliminary estimates of the weights of the two brackets required per spacecraft are 1 kg for the main SEP box and 0.2 kg for the North-South SEPT. While these estimates are thought to be reasonably conservative, no vibration analysis has yet been done to verify that they are sufficient.

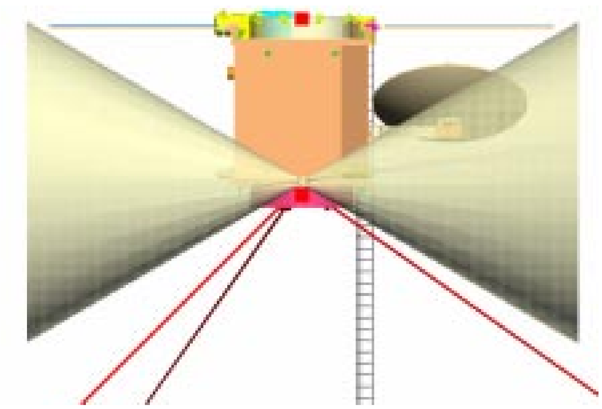

Figure C.3-3. Shows the North-South SEPT field of view clearing the ends of the solar array and the SWAVES antennas. The North-South SEPT telescopes have the same location on the leading STEREO spacecraft as on the trailing spacecraft.

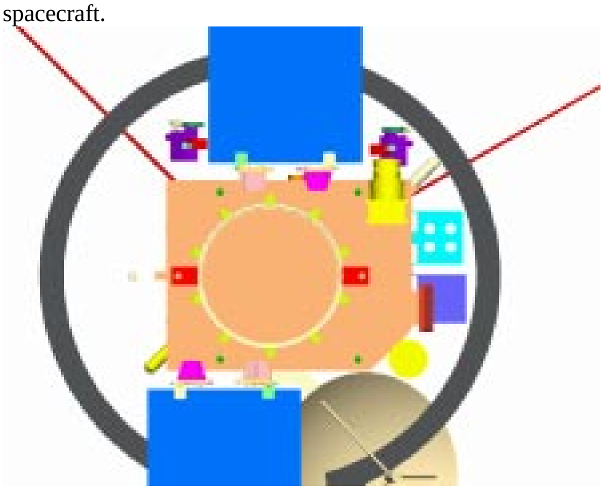

Figure C.3-4. Top View of IMPACT/SEP on the Stereo spacecraft. The dark circle in the figure below depicts the dynamic envelope of the fairing. The SEP positioned underneath the Plastic instrument at the top right corner of the spacecraft body corresponds to the trailing spacecraft. Note that this SEP is about as far out from the body of the spacecraft as is allowed by the fairing envelope. The other SEP depicted (near the top left corner of the spacecraft body) corresponds to the leading spacecraft. The North-South SEPT is in the same position on both spacecraft (outboard at the center-left side of the spacecraft).

The remaining impingements of SEP fields of view with the spacecraft are illustrated in Figures C.3-5, 6, and 7 and described in their respective captions. Based on Figure C.3-5, we have requested that, if possible, two corners of the lower deck of each spacecraft be cut back. This would presumably also result in a weight savings to the spacecraft. Impingements of the LET field of view are illustrated in Figures C.3-6 and C.3-7. The LET field of view intercepts one edge and corner of the spacecraft for both the leading and trailing spacecraft as well as the front edge of the Plastic instrument on the trailing spacecraft. We have requested corresponding chamfering of the edge and corner to help fully clear these fields of view.

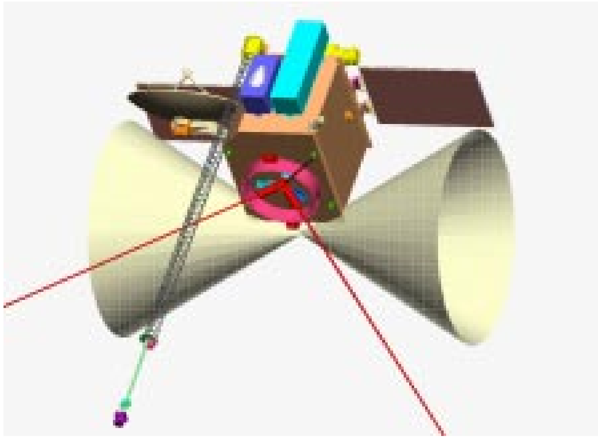

Figure C.3-5. Shows the impingement of the North-South SEPT fields of view with the corners of the lower deck of the STEREO leading and trailing spacecraft.

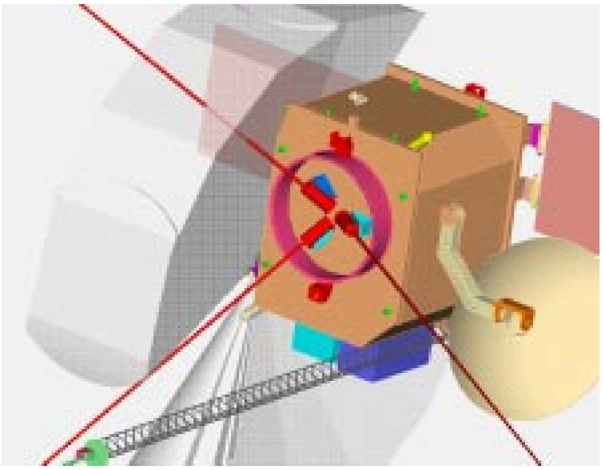

Figure C.3-6. Impingent of the IMPACT/SEP LET field of view with the edge of the spacecraft body and with the corner of the lower deck of the trailing STEREO spacecraft. There is a similar impingement on the leading spacecraft

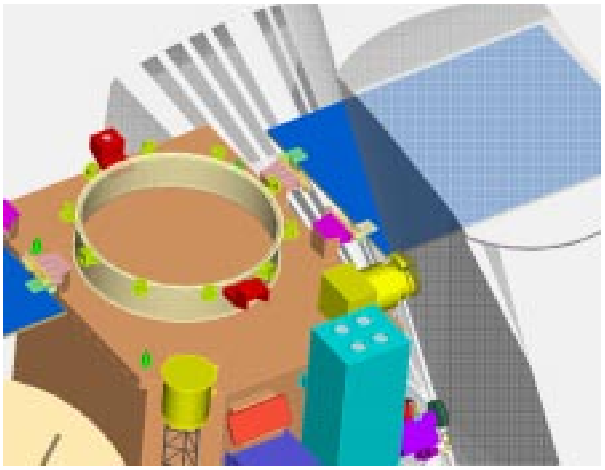

Figure C.3-7. Impingement of SEP/LET forward field of view on the trailing STEREO spacecraft with the front of Plastic.

C3.0.3 Beacon Data

Figure C.3-8 summarizes the species and energy ranges that will be covered by beacon data from SEP. The SEP beacon data in the context of the overall IMPACT beacon data are included in Table C.1-1. SEP beacon data will require 6.1 bps and give 1 min time resolution information on the energetic particles at the two STEREO spacecraft locations. In addition, LET will provide the $^3He/^4He$ ratio from 3 to 6 MeV/nucleon.

C.3.0.2 Resources

The resources required by SEP are summarized in Table C.3-3. Those resources do not include mass for SEPT doors. The SEPT doors were not part of the original proposal; however, during Phase A it was determined that, during the early part of the mission, the spacecraft will undergo periods of up to 20 minutes during which time the SEPT telescopes might point directly towards the Sun. The SEPT doors will be required to be kept closed until after such maneuvers are completed. Requirements for survival heaters are not yet determined.

There has been some growth in SEP resources since the proposal. Some are due to required reconfigurations (SEP brackets, heavier compromise HET), while others are due to better definition of the instruments.

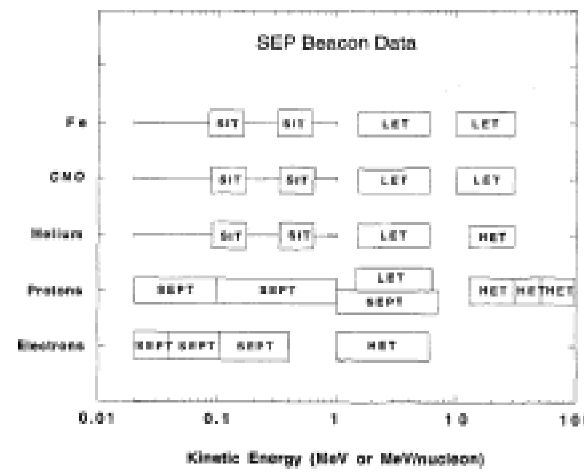

Figure C.3-8. Species and energy ranges covered by beacon data from SEP.

Subsystem	Mass (g)	Power (mW)	Bit-Rate[1] (bits/s)	Pyros	Survival Heaters
SEPT-North/South	440	520	60	1	TBD
SEPT-NS Harness	150				
SEPT-Ecliptic	460	520	60	1	TBD
SIT	930	660	240	1	TBD
LET	510	180	320		TBD
HET[3]	700	70	120		TBD
SEP Main Box					TBD
Enclosure	750				
Common Electronics	940	1550			
Brackets[2]	1200				
Thermal Blankets	100				
Totals:	**6180**	**3510**	**800**	**3**	**TBD**

[1]Per new bit-rate allocation = 4x proposal
[2]Brackets estimated for spacecraft design presented at SRR
[3]Compromise HET

Table C.3-3. STEREO/IMPACT/SEP Resource Requirements (per spacecraft).