C.2.3 Suprathermal Electron Detector (STE)

STE is a new instrument to cover the primary energy range (~2-20 keV) of the impulsive electron events which generate type III radio bursts, the shock accelerated electrons which produce type II radio emission, and the superhalo electrons (whose origin is unknown) during quiet times. STE will have more than two orders of magnitude larger geometry factor × observing time product than previous detectors in this energy range, with much lower background. Thus, it will be able to detect and analyze even very weak impulsive electron events, making many more available for diagnostics of ICMEs and solar wind structure, i.e., determining magnetic field line lengths and and tracing magnetic connection to coronal sources.

C.2.3.1 System Description

STE utilizes passively cooled silicon semiconductor detectors (SSDs), which measure all energies simultaneously (100% duty cycle). Up to now SSDs used for particle detection have had relatively high capacitance (large area), and high leakage current, resulting in electronic noise thresholds of >~15 keV.

Small, low capacitance (<~1 pf), low leakage current SSDs with state-of-the-art electronics have been developed to detect X-rays down to ~1 keV with excellent (<~0.2 keV) energy resolution. Arrays of 64 or more such SSDs on a single silicon wafer, together with all their low power analog electronic chains on a ASIC chip, have been developed at UCB. Lab tests of 0.5 cm^2 area, 300 micron thick, cooled (-50° C) SSDs with ~500 Å Si equivalent window dead layer (flight spares of the SSDs successfully flown on Equator-S) show that electrons down to ~5 keV energy can be detected even with an SSD capacitance of 26 pf.

The STE consists of two arrays consisting of four SSDs in a row, each SSD ~0.1 cm^2 area and ~500 micron thick, surrounded by a guard ring (Figure C.2.3.1) to minimize surface leakage current. With present state of the art electronics, the much lower capacitance (~2 pf) of these SSDs, the electronic threshold is expected to be ~800 eV. With the same window dead layer as Equator-S SSD, electrons down to ~2 keV should be detected, with ~300 eV FWHM electronic energy resolution.

Each array looks through a rectangular opening that provides a ~20°×~80° FWHM FOV for each SSD (80° direction perpendicular to the ecliptic). Adjacent FOVs are offset from each other by ~20° for a total FOV of ~80°×80°, and pitch angle resolution of ~20°. The two arrays are mounted back to back on a thermally isolated ~8 cm × 8 cm cold plate, with FOVs looking in opposite directions, centered about 25° offset from the average Parker spiral field direction to avoid the spacecraft. STE is located just inboard of SWEA on the end of the MAG boom, to provide an unimpeded field of view and to keep it in the spacecraft shadow. Simple passive cooling provides temperatures of <~-50° C. Similar radiative cold plates (which reached ~-70° C even though direct Sun was viewed on every spin) have been successfully flown by UCB on IMP-6 and ISEE 1,2, and 3.

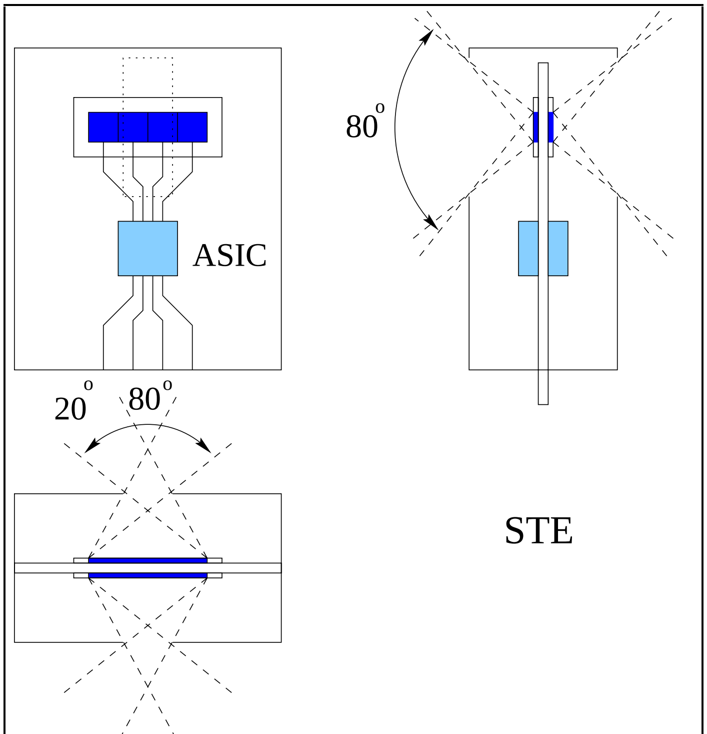

Figure C.2.3.1 STE Detectors

The SSD background is expected to be far lower than for previous detectors in this energy range. The primary background source at 2-20 keV is diffuse sky X-rays (~1 c/s), but these are < 12 % of the minimum superhalo count rate (~9 c/s). Penetrating particles leave >200 keV (minimum ionizing), and the rates for cosmic rays are <0.2-0.4 c/s. Low energy ions can penetrate the window and stop. The STE FOV excludes solar wind ions, but pickup ions fill a shell in velocity space of radius ~V_{sw} (solar wind speed) centered on the solar wind (Mobius et al., 1999). For typical V_{sw} ~400 km/s, pickup He^+ are likely to be detected from directions within ~45° of the solar wind. The SSD whose FOV is closest to the solar wind could see He^+ count rates of a few hundred per sec, while the other SSDs should see ~10 c/s each, dominated by superhalo. Of course, at higher V_{sw} more pickup ions will be detected, in more SSDs.

C.2.3.1.1 Sensor Electronics. Figure C.2.3.1.1 shows the STE block diagram. Custom designed low power (~10 mW per chain) preamp-shaping amp electronics are used (based on the X-ray SSD electronics). Each preamp-shaping amp is followed by a low power 11-bit analog-to-digital converter (ADC), from HESSI (~7 to 16 mw per chain, depending on count rate) to provide ~0.25 keV/channel over the energy range for stopping electrons of ~1.5 to ~500 keV. Thus STE provides overlap with SEP/SEPT above ~20 keV. Only these digital signals are sent back to the IDPU. As in the UCB WIND and ISEE 3 instruments, a ramping pulser provides electronic calibration while the minimum ionizing shoulder provides an absolute calibration feature. The electronics is divided into a preamp, co-located with the SSD to minimize noise, and the shaper / ADC / Accumulator / IDPU Interface / Power Converter which is co-located with the SWEA electronics nearby. The Interface and power converter electronics are shared with SWEA. This division optimizes the noise immunity of STE while minimizing the power dissipation in the STE unit to help get the unit cold.

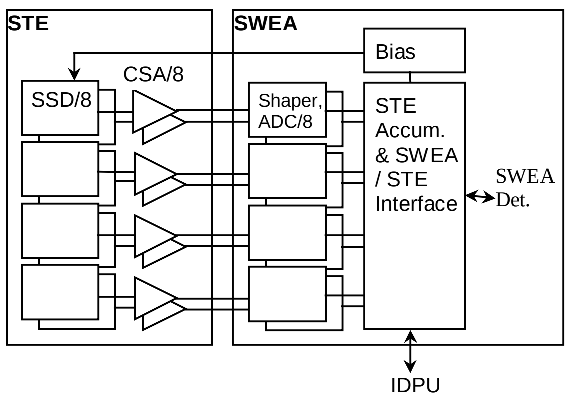

Figure C.2.3.1.1 STE Block Diagram

C.2.3.2 Field of View

STE is sensitive to reflected light so the primary consideration for STE pointing is to have a clear FOV with no booms or other intrusions. Pointing accuracy and knowledge should be ~1°.

C.2.3.3 Data Rates and Format

The counts are sorted into 16 quasi-logarithmic energy channels and telemetered in 8 bit compressed numbers every 60 s, for a total of 8 det $\times$ 16 ch $\times$ 8 bits / 16 s = 64 bps. For studies of Type II and III solar radio emission generation and of interplanetary shock acceleration, high time resolution (2 seconds) data are sent to the Burst Memory (see IDPU section C.4). STE also provides low rate beacon mode data consisting of data averaged into 2 directions by 3 Energies every minute.

C.2.3.4 STE Aperture Covers

The STE instrument requires aperture covers that can be opened and closed. For launch, and during s/c sun-pointing and thruster operations, the covers must be closed, during early orbit, and when on station, the covers are open. The covers are actuated by a shape memory alloy (SMA) spring mechanism that causes the doors to rotate in and out of the sensors' FOV. The pair of doors are connected by a thin shaft, allowing 1 actuator mechanism for both. The method of activation is thermo-electric: current passing through the SMA spring causes a phase change in the SMA, providing a force that pushes the door to its opposite position. Power requirements are 500 mW. This method of actuation has been successfully used on LP for the ESA covers, and is being used on Hessi attenuators. The STE aperture covers and mechanisms will be fabricated at UCB SSL.

C.2.3.5 Ground Support Equipment

Bench electronics, lab equipment, and radiation sources are used to test and calibrate the STE system prior to integration with SWEA. After integration with SWEA, the IDPU Simulator GSE is used to control STE and display its data (see IDPU GSE section C.4.2.6)

C.2.3.6 Instrument Requirements

The STE interface requirements information is summarized in Table C.2.3.6. The electrical interface shall be via the common SWEA/STE serial interface to the IDPU. The mechanical interface is to the IMPACT boom, just inboard of SWEA. This location provides a clear FOV that is well isolated thermally from the spacecarft and in the shade to aid in keeping the detectors passively cooled. Note that a recloseable cover is currently believed to be required to avoid detector contamination during thruster firing, as well as possible detector overheating from sunlight exposure in off-nominal spacecraft orientations. This cover requirement is relatively new, and is not in the current Project mass allocation.

Table C.2.3.6 Interface Information

Location	IMPACT boom,just inboard of SWEA
Mass	350g + 60g for reclosable cover
Power	300mW, avg., 600mW peak during very large solar flares
Data Rate	64bps (plus 1.6bps beacon mode)
Field of View	Two opposite 80°x80°
Pointing Direction	Parker Spiral
Pointing Knowledge	±1°, after the fact
Pointing Stability	No Requirement
Commands	Bias supply voltage, Thresholds
Thermal	Cooled passively to -50°C by being in shadow and thermally isolated from boom.
Cleanliness	Experiment contains silicon semiconductor detector. Standard precautions for these devices apply.
Purge	Continuous purge of sensor with pure dry N_2 gas required whenever the experiment is mounted on the S/C.
Other	Because the semiconductor detectors have thin windows and low thresholds, and are cold, they are extremely sensitive to condensation of thruster plumes. A reclosable cover is baselined.

C.2.3.7. Calibration

The STE sensors will be calibrated with electron and ion sources at UCB.

C.2.3.8 Development Plan

During Phase A and early Phase B, the design will be developed and interfaces finalized. The development items are the detectors and the front-end electronics. Then a prototype instrument will be fabricated and tested to prove the design. In phase CD the flight instruments shall be fabricated, tested, and calibrated. The detectors shall be provided and the analog front-end electronics shall be designed at LBNL. UCB shall fabricate the flight electronics, and build, test, and calibrate the flight assembly. Flight fabrication will follow the Performance Assurance requirements called out in the IMPACT PAIP, included in an appendix to this document.

C.2.3.8.1 SSD Development. During Phase A and early phase B, the capabilities of the SSD in the intended application will be studied using prototype detectors. This will result in an optimal configuration for making the desired measurement and a better idea of the performance and sensitivities of the detectors.

C.2.3.8.2 Analog Electronics Development. The baseline analog front-end electronics for STE is based on the low power custom electronics developed for X-rays at Berkeley, suitably modified to use flight qualified parts. An alternative under study is to use the ASIC being developed for HET, LET and SIT. The advantages of the ASIC are some power savings and commonality of development with those other instruments. The disadvantage is a lower throughput capability that degrades performance somewhat during flares, and the added risk involved in the ASIC development. Either solution involves screening commercial parts for flight application, which makes the parts long lead items. We will continue to develop both options in parallel and make a decision early in phase B.