C.3.1 Suprathermal Ion Telescope (SIT)

C.3.1.1 System Description

The Suprathermal Ion Telescope (SIT) measures the elemental composition of He - Fe over the energy range ~30 keV/nucleon to 2 MeV/nucleon, thus covering the energy range between the Low Energy Telescope (LET) portion of the IMPACT investigation and the solar wind and suprathermal ion observations to be made by the PLASTIC investigation. The scientific objectives addressed with SIT measurements are discussed in section B.

SIT is a time-of-flight mass spectrometer whose telescope cross section is shown in Figure C.3.1-1, and the energy ranges covered are in Table C.3.1-1. The field of view (FOV) is defined by the thin foils at the front of the telescope, and the solid state detector at the back. The FOV full angles are 17° x 44°, with the 44° angle in the ecliptic plane as shown in Figure C.3.1-2. The telescope analyzes ions that enter through thin entrance foils (1000Å Ni) and stop in the solid state detector (see Figure C.3.1-1). When an ion enters the telescope as shown, secondary electrons are emitted from the inner surface of the entrance foil and also from the front surface of the solid state detector. These secondary electrons are accelerated and deflected by ~1kV electrostatic fields so that they strike chevron microchannel plates (MCPs), providing START and STOP signals for the time-of-flight measurement. The solid state detector signal provides a measurement of

Table C.3.1-1 SIT Energy Ranges for Typical Species

Species	Energy Range (keV/nuc)	Mass Resolution at 100 and 1000 keV/n
^{1}H	120 - 8100	0.36-0.12
^{4}He	42 - 8100	0.35-0.50
^{12}C	23 - 4900	0.67-1.4
^{16}O	22 - 3700	0.85-1.9
^{20}Ne	20 - 3000	1.1-2.3
^{24}Mg	18 - 2500	1.3-2.8
^{28}Si	18 - 2100	1.5-3.2
^{32}S	18 - 1900	1.7-3.7
^{56}Fe	16 - 1150	2.9-6.5

Notes: ^{1}H efficiency for detection is <1%, and is shown for reference only
Discriminator threshold 75 keV
SSD amplifier range: 75 keV - 58 MeV
SSD thickness: 500 microns

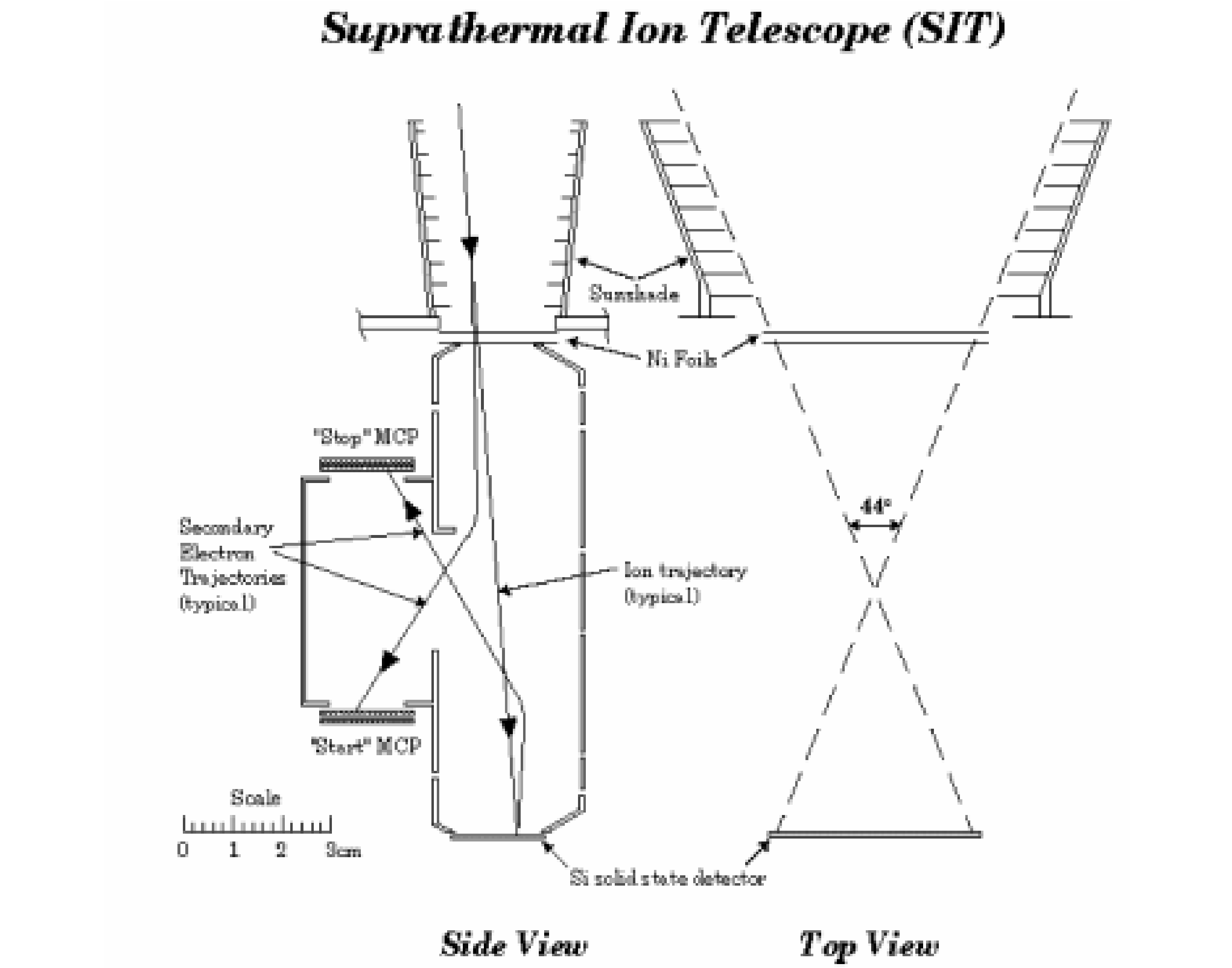

Figure C.3.1-1 The Suprathermal Ion Telescope (SIT)

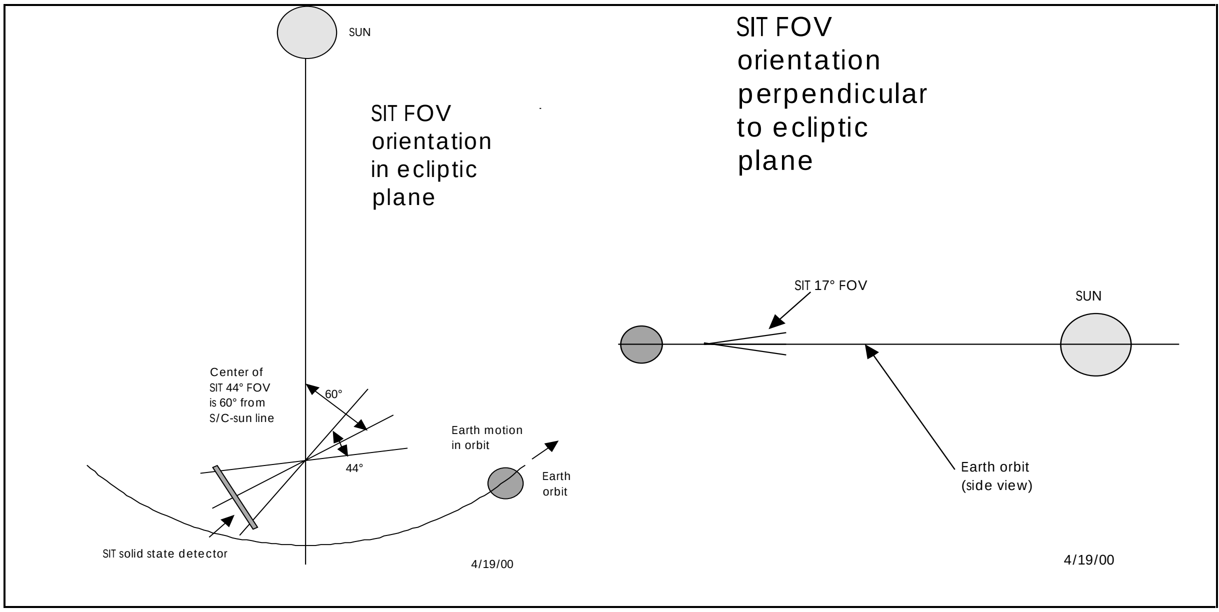

Figure C.3.1-2 SIT FOV orientation

the kinetic energy of the ion. The time-of-flight *T*, the energy *E*, and the 10 cm path length in the telescope (*L*) are then combined to derive the mass of the ion: $M=2E(T/L)^2$. The incident energy is obtained by correcting for the energy losses in the entrance foil and detector window. The MCP and detector areas are each 6.0 cm^2 (1.5 x 4.0 cm). The SIT geometry factor after allowing for mesh transparencies is 0.30 cm^2 sr, and thus is large enough to allow study of even small impulsive solar particle events.

Solar ultraviolet radiation hitting the front foil may cause secondary electron emission, thus increasing background in the instrument. In addition the foil aperture serves a thermal role by allowing emission of thermal radiation from the telescope. The SIT sensor therefore includes a sunshade that, taken together with the telescope look direction shown in Figure C.3.1-2, prevents sunlight from striking the telescope entrance foil.

The entrance foils of SIT are twin 1000Å Ni foils mounted on a supporting mesh. The foils are protected during spacecraft I&T and during launch by a cover that deploys after launch. Twin foils are used to provide redundant protection against pinholes that may develop during launch vibration.

Figure C.3.1-3 is a block diagram showing the major subsections and interfaces, and data flow within SIT. For each ion triggering the telescope, time-of-flight and energy information is obtained. The time-of-flight is measured using a gate-array technique, achieving excellent accuracy with exceptionally low power. Solid state detector signals are amplified, then

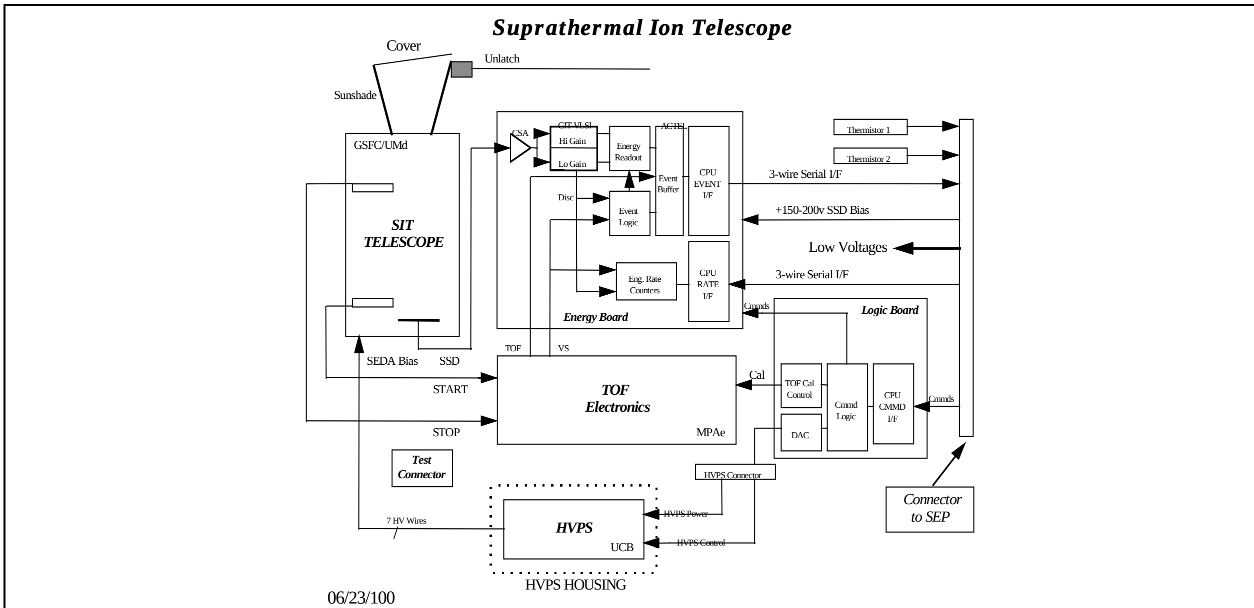

Figure C.3.1-3 SIT block diagram. Electronic interface is internal to SEP package analyzed using the same Caltech ASIC used in the LET package. Simple control, housekeeping, and command processing circuits account for the remainder of the SIT electronics. SIT uses a common low-voltage power supply and obtains detector bias from the SEP electronics. SIT contains a dedicated high voltage (~3.5 kV) power supply for the microchannel plate/secondary electron assembly. SIT interfaces with the SEP electronics and shares a common spacecraft interface with the other SEP sensors.

Full information on selected ion events is telemetered, namely the ion's time-of-flight and solid state detector energy, along with timing information. Telemetry limits the broadcast of complete events to 5.70/second. In order to carry out rapid determination of spectra near, e.g., CME shocks, much larger numbers of events are required. This is accomplished by sending data from all events to a central processor in the SEP electronics as described in section C.3.5. There, SIT events are classified into mass and energy bins that are summed on-board to allow rapid accumulation of flux and spectra.

The mass and energy resolution of SIT are sufficient to identify ^{3}He, and major elements (^{4}He, C, N, O, Ne, Mg, Si, and Fe) accelerated in impulsive solar flares as well as CME associated solar particle events and interplanetary shocks. As an example, Figure C.3.1-4 shows the excellent separation of ^{3}He and ^{4}He at 150-250 keV/nucleon by SIT, using data from an identical sensor on the WIND spacecraft. Observations such as these are essential in the identification of impulsive solar particle events, since many of these events do not produce measurable intensity increases above 1 MeV/nucleon.

Technique/justification: heavy ion spectra in the sub-MeV/nucleon range are beyond the range of the *dE/dx* vs. residual energy technique, except for extremely thin *dE/dx* detectors that have poor

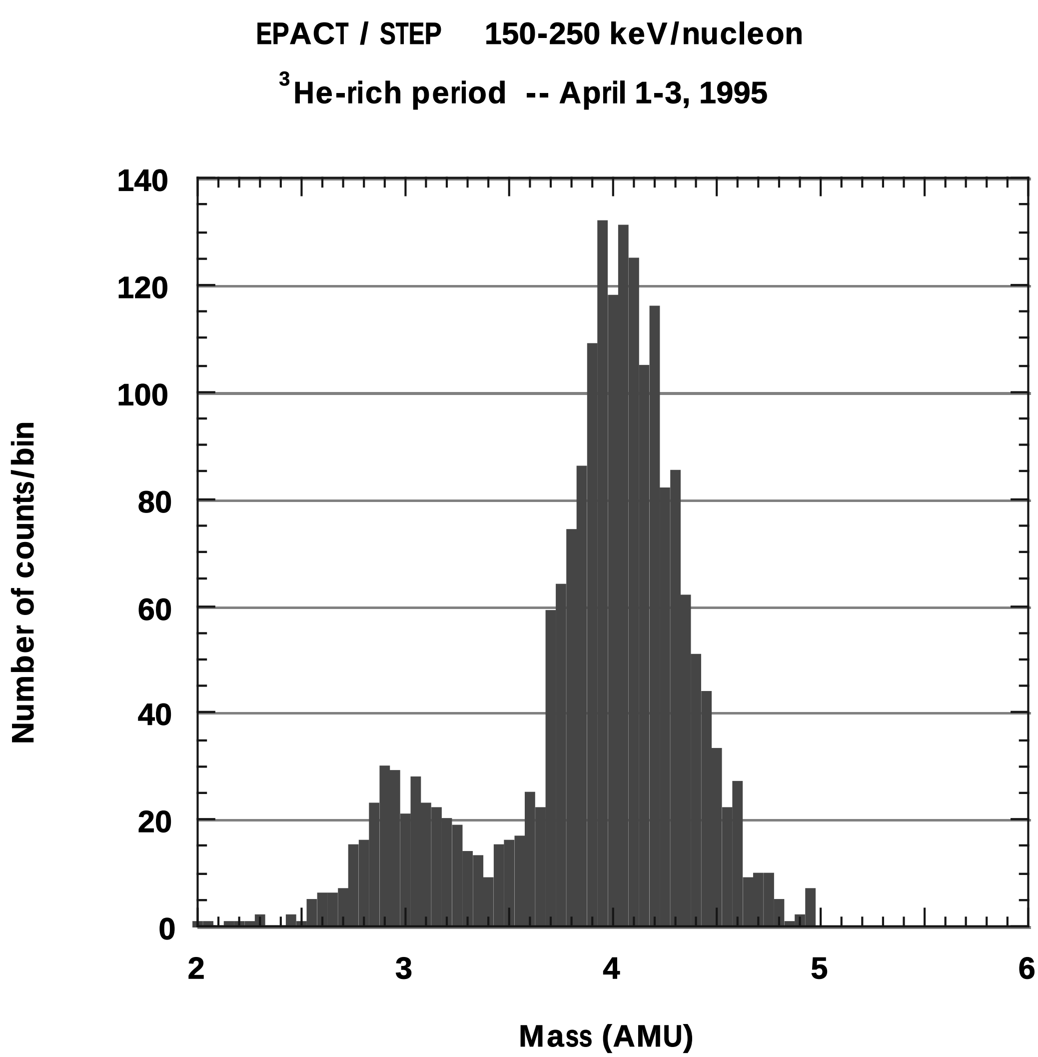

Figure C.3.1-4 ^{3}He / ^{4}He separation from STEP telescope on WIND (identical design to SIT) performance due to small size, non-uniform depth, and large capacitance. Flow-through proportional counters can be used to achieve thresholds around 0.5 MeV/nucleon, but not lower. For the energy range of the SIT, time-of-flight (TOF) mass spectrometry is the technique of choice.

SIT operates in its normal mode continuously. The only commanding is occasional (every few months) adjustment of MCP bias, as may be required if MCP gains drift. The multi-parameter measurements returned by SIT for each ion allow for self-calibration of the instrument in space. Any changes in detector response will result in a shift of particle tracks in the time-vs-energy data, which can be easily detected and corrected. If necessary, there is a provision of uploading new look-up tables for the on-board identification of species. SIT uses no expendables.

The SIT sensor is enclosed in a box that is attached to the main SEP box. Electronics boards are mounted within the SEP electronics box.

C.3.1.2 Pointing Accuracy

Pointing knowledge is not critical but is desired to be ±1° after the fact.

C.3.1.3 Power Requirements

Power requirements for regulated low voltages are summarized in Table C.3.1-2. Requirements for heaters, if any, will be identified when the thermal design is carried out.

Table C.3.1-2 SIT Power allocation

Subsystem	**mW**
Telescope	0
Energy electronics	83
Time-of-flight	365
Digital electronics	53
High Voltage Power Supply	160
Housekeeping	0
TOTAL:	**661**

C.3.1.4 Data Rates and Format

SIT requires 240 bits/s to meet its scientific objectives. This bit rate is allocated as shown in Table C.3.1-3.

Table C.3.1-3 SIT Bit Rate allocation

Data Item	**bits/s**
Pulse Height Analysis Events - 36 bits/event; 5.7 events/s	205.2
128 low resolution rates, 12 bits each (log compressed); readout interval: 128 S.	12.0
9 high resolution rates; 12 bits each (log compressed); readout interval: 8 S.	13.5
6 discriminator rates; 12 bits each (log compressed); readout interval 8 S.	9.0
Data record header & trailer	0.3
TOTAL:	**240.0**

C.3.1.5 On-Board Data Storage

SIT on-board storage is primarily in look-up tables and particle mass/energy "boxes" for on-board particle identification. This data storage is part of the SEP central DPU; SIT needs in this area are approximately 29 kBytes. The storage in the dedicated SIT electronics boards shown in Figure C.3.1-3 is limited to several 10s of bytes for command state, etc.

C.3.1.6 Dedicated Experiment Processor (DEP) Requirements and Software

SIT shares the SEP processor with the SEPT, LET and HET telescopes. The anticipated maximum event rate from the SIT sensor to this processor can be accurately determined using >5 years of data from the WIND spacecraft: a processor maximum event rate of 1000 events/second is sufficient.

C.3.1.7 Ground Support Equipment

The deliverable SIT GSE is part of the overall SEP GSE; there is no deliverable stand-alone unit. Non-deliverable GSE used to develop, test, and calibrate the SIT subsection of SEP will be IBM-PC based and will make use of existing CAMAC crates and modules at the University of Maryland. This equipment will be used to fully evaluate the operation of the SIT experiment in real time, both in lab testing and at accelerator calibration. It will provide a permanent record of the test data for further detailed analysis. The non-deliverable GSE will include a SEP processor simulator that connects to the SIT boards through the connectors indicated on the right side of Figure C.3.1-3.

C.3.1.8 Instrument/Spacecraft Interface

There is no separate SIT mechanical or electrical interface with the spacecraft except possibly for the cover release command line, and spacecraft-powered thermistors if desired by the spacecraft team.

C.3.1.9 Calibration Plan

SIT can be triggered by laboratory alpha-particle sources, whose emission energies near 1 MeV/nucleon fall near the center of the SIT energy response. The basic particle response of the instrument can thus be verified in our laboratory vacuum systems, and during spacecraft thermal vacuum tests. Calibration of the instrument's response to heavy ions, and to high count rates, requires calibration at a van de Graaff accelerator. This calibration may be carried out at the Brookhaven National Laboratory Tandem van de Graaff, or at the Los Alamos National Laboratory van de Graaff. Based on more than 13 years flight time logged by the SAMPEX, Wind, and ACE instruments, flight stability for SIT should be excellent (Mason *et al.*, 1993; 1998). If drifts do occur, the instrument's internal mass binning tables can be modified by ground command.

C.3.1.10 Heritage

The SIT telescope is *identical* to the EPACT/STEP telescope successfully operating on the WIND mission since November 1994 (von Rosenvinge *et al.* 1995). Thus, the SIT telescope design is complete, except for a the sunshade/closable cover. We have many spare parts from the WIND/STEP development, and will use these for SIT, thus reducing the number of parts that need to be constructed. Due to shelf-life considerations, new MCPs and solid state detectors will be procured for the SIT flight instruments.

The energy system electronics will include flight-proven AMPTEK preamps, and ASICs provided from Caltech based on the successful ACE design. The MCP bias supply will be provided by UCB, using a design developed for the HESSI Small Explorer spacecraft. The TOF system is a new development by MPAe to provide the necessary time-of-flight information at minimal power as required on the STEREO mission.

C.3.1.10.1Development plan. Trades in progress include the Thermal actuator cover release vs. squib; this item will be coordinated with other SEP door requirements.

New technology development includes the Solid state detector ASIC developed by Caltech (see section C.3.3.3.2), and the low power gate array TOF developed by Max-Planck-Institute für Aeronomie.

Long lead items for SIT include the solid state detector, microchannel plates, and electronics parts. We assume there will be a common SEP buy on ACTEL parts

Breadboard and engineering model plans include electronics boards that will be constructed for all SIT functions, an engineering model telescope that will use existing spare parts from STEP/WIND and a simulator for the interface to SEP provided by Caltech.

The SIT fabrication plan involves: flight mechanical parts, including telescope and electronics box provided by T. von Rosenvinge at GSFC (the telescope will use existing WIND/STEP parts inventory insofar as possible, and fabricating additional parts only as necessary); flight electronics boards all but TOF and HVPS board fabricated and trimmed at Caltech and/or under the direction of T. von Rosenvinge group at GSFC; the flight TOF board provided by Max-Planck-Institute für Aeronomie; the flight HVPS provided by University of California Berkeley; and integration, checkout, and trim done by University of Maryland.

The calibration plan involves the University of Maryland with the option to collaborate with Los Alamos for Tandem van de Graaff use. There are no other plans to use special facilities.

C.3.1.11 Special Requirements & Miscellaneous

Prelaunch: purge may be required to protect the solid state detector and microchannel plates. Spacecraft level testing must be in oil-free vacuum systems. Postlaunch: closable cover to be opened at the earliest time consistent with spacecraft operations and point directions. No routine commanding, except for occasional (every few months) adjustment of microchannel plate bias voltage.

SIT flight performance will be monitored by SEP Experiment team; calibrated data will be provided to the UCB DM for archiving by the University of Maryland instrument provider.

C.3.1.12 Roles & Responsibilitie

Prof. Glenn Mason, University of Maryland: has overall responsibility for the development of SIT and delivery of SIT data postlaunch. Dr. Axel Korth, Max-Planck-Institute for Aeronomy, Lindau, Germany: has overall responsibility for development and delivery of SIT time-of-flight boards. Dr. Robert Lin, University of California, Berkeley, will provide the HVPS. Peter Walpole, University of Maryland serves as the SIT system engineer. Dr. Joseph Dwyer, University of Maryland carries out SIT data system design, pre-launch calibration, and postlaunch data system design. Tommy James, University of Maryland (consultant), advises the team on heritage mechanical systems from the WIND/STEP instrument, and Edvin Tums, University of Maryland (consultant) advises on SIT analog electronics. Contributions to SIT development of the T. von Rosenvinge group at GSFC are described above under section C.3.1.10.1.

C.3.1.13 Outstanding Issues and Concerns

A portion of the SIT electronics, i.e. the time-of-flight board, is to be provided by the Max-Planck-Institut für Aeronomie at Lindau, Germany. This activity is therefore of a type that might fall under the rules and regulations of the International Traffic in Arms Regulations (ITAR). The University of Maryland legal counsel has reviewed this issue, and made the following determination (March 31, 2000):

"University Counsel from the Legal Office (Anne Bowden) and the Director of the Office of Research Administration and Advancement (Erica Kropp) have reviewed the Department of State-controlled export law and regulations and Dr. Glenn Mason's technical evaluation of ITAR Category XV on the Munitions List (dealing with Spacecraft systems and associated equipment) and have determined that Dr. Mason's work on the Suprathermal Ion Telescope for the STEREO mission falls within the fundamental research exemption provided under the law."

We therefore anticipate no impact to the SIT development due to ITAR.