Options for the SEP/IMPACT Subsystem of NASA's STEREO Mission

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Abstract: The IMPACT Investigation for NASA's STEREO mission includes a Solar Energetic Particle (SEP) subsystem comprised of four sensor systems that collectively provide measurements of 0.02 to 100 MeV/nucleon particles. Recently it was learned that Waseda University, one of the foreign partners that was to provide key hardware for SEP, was not successful in securing funding. This proposal discusses three possible options for mitigating the loss of the Waseda University contribution and at the same time maximizing the scientific output of the SEP system. In particular, a proposed High Energy Telescope based on existing spare detectors could provide all of the required measurements.

1. Introduction

The SEP subsystem for IMPACT includes four sensor systems (SEPT, SIT, LET, and HET) that are designed to provide key measurements needed to study solar particle acceleration processes and to complement other measurements to be made by STEREO. This comprehensive package measures solar particle composition over the energy range from ~0.02 to 100 MeV/nucleon (see Figure 1) using state-of-the-art designs that require only very limited resources. It also provides a number of key parameters for the STEREO Beacon System, including measurements of 10 to 100 MeV protons and heavier ions that can be used to forecast radiation levels for the Space Station and other space systems.

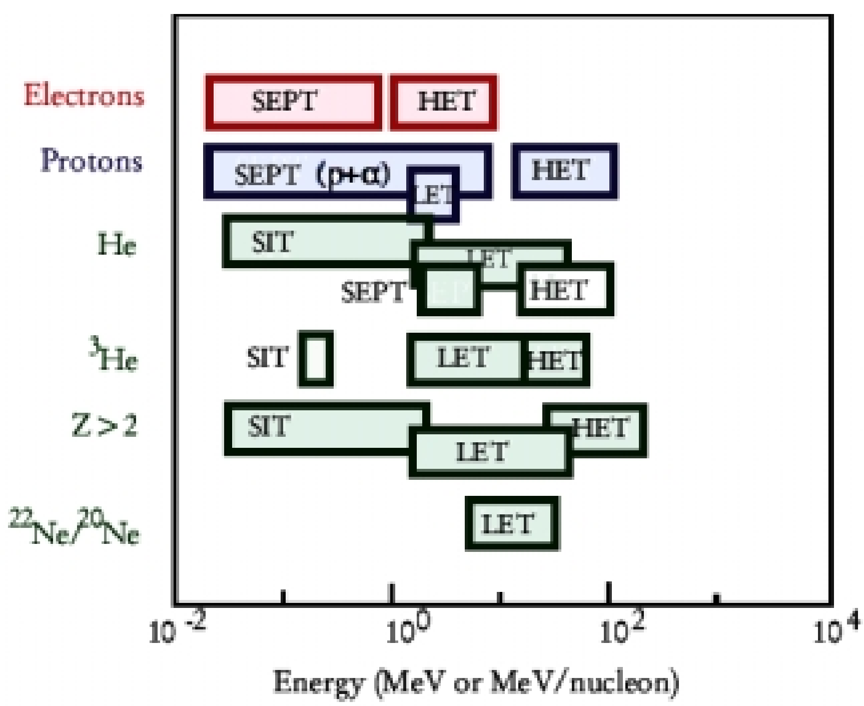


Figure 1: Energy range over which the four SEP sensors can measure various species.

Table 1 summarizes key aspects of these four sensors, including the institutions selected to carry out their development. Schematic representations of the four telescopes are shown in Figure 2. Note that, as a collaborator on the IMPACT/SEP team, Waseda University was to provide several essential hardware items:

a. Two fully-assembled and tested High Energy Telescopes (HETs; see Figure 2), including detectors and telescope housings (but not including the associated electronics).

b. The L2 and L3 detectors for LET (see Figure 2)

c. The power supply to provide detector bias for all solid-state detectors in SEPT, SIT, LET and HET (one bias supply for each spacecraft).

Unfortunately, Waseda University was unable to secure funding for participation in STEREO. The IMPACT proposal estimated the value of the Waseda University contribution to be ~$680K; we have now made a more careful estimate of this contribution and arrive at a value of RY $730K. Most of these costs are associated with the HET detectors and housings.

Table 1: SEP Sensors

Sensor	Species	Energy Interval (MeV/nucleon)	Total Geometry Factor (cm2sr)	Contributing Institutions (as proposed)
SEPT	Ions	0.02 to 7	0.5	Kiel, ESTEC
	Electrons	0.02 to 0.4	0.6	
SIT	$Z \geq 2$ Comp.	0.03 to 2	0.30	Maryland, MPI-Lindau,
	3He/4He	0.15 to 0.25		GSFC*, Caltech*, UCB*
LET	Protons	1.5 to 6	4.5	GSFC, Caltech, JPL
	$2 \leq Z \leq 28$ Comp	1.5 to 30		Waseda University*
	3He/4He	2 to 16		
	22Ne/20Ne	5 to 30		
HET	H, He	13 to 100	2.4	Waseda University,
	$Z \geq 2$	30 to 100		Caltech, GSFC, JPL
	Electrons	1 to 6		

* supporting role

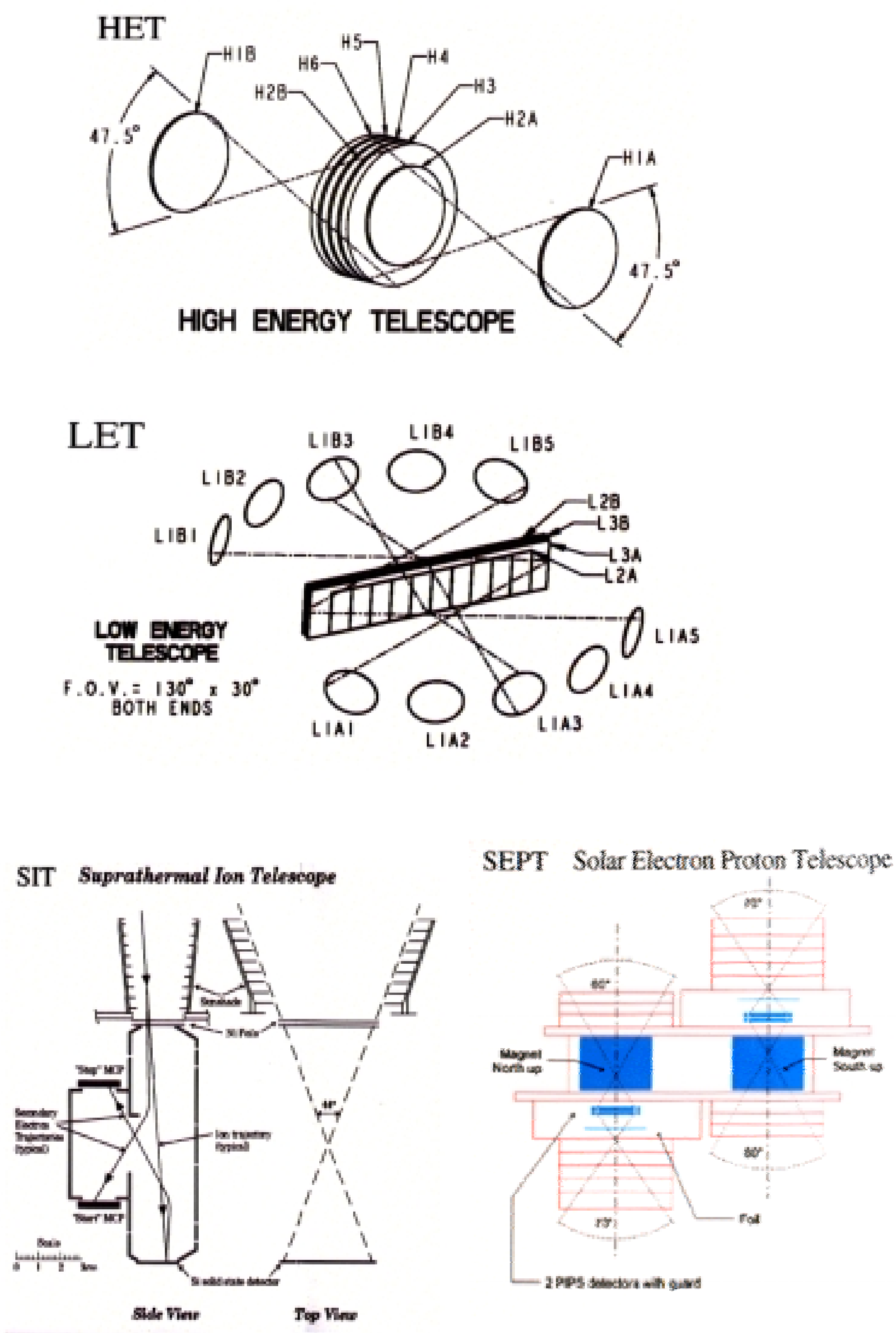


Figure 2: Schematic illustrations of the originally proposed designs for the four SEP sensors, SEPT, SIT, LET, and HET.

2. Options

Over the course of the past two months we have attempted to look for options that would make it possible to build all three sensors (LET, SIT, and HET) within our original cost allocations. Clearly, the major challenge is to provide the HET telescope. Among the options considered were: a) using refurbished HETs (of a similar design) from Voyager. This option turns out to be more costly than Option 3 below, and has additional risk. b) Seeking potential foreign contributors (this effort was unsuccessful); c) Implementing simplified designs for HET; d) the use of existing hardware; and e) modifying LET to cover energies up to 100 MeV (this ”hybrid” LET/HET approach also turns out to be more expensive than Option 3 discussed below). We have been successful in developing a lower cost design for HET (see below), but we have not been able to find a solution that provides all three sensors within the presently allocated costs. In essence, we find that the allocated funding levels are adequate to provide any two of these three sensors (LET, HET, and SIT), but not all three. As a result, we present three options for consideration. A breakdown of the estimated resources required to implement these options can be found in Section 3.

Option 1: SEP as Proposed

In this option, Caltech, GSFC, and JPL would share the effort that was to have been performed by Waseda University, including the fabrication of HET and the procurement and testing of the LET L2 and L3 detectors. The bias supply, required by all four SEP sensors, could be manufactured by a subcontractor (we have an estimate from a qualified subcontractor, Space Instruments, Inc., for $80K). We have identified at least one detector manufacturer (Micron Semiconductor) who is interested in providing the required detectors for both LET and HET. This manufacturer also provided a large number of detectors for the Caltech/GSFC/JPL experiments on ACE. As noted above, the additional funding required to implement this option is $730K.

Option 2. No HET

If we do not provide a HET telescope and its associated electronics, it is just possible to provide the proposed LET and SIT instruments and the bias supply within the existing funding. In this case, the following would be missing from the scientific data provided by SEP:

- The proton and He response of SEP would extend from ~0.03 to ~10 MeV/nucleon; but there would be no solar proton or He measurements in the 10 to 100 MeV/nucleon range that was covered by HET.

- The electron response of SEP would extend from 0.03 to 0.4 MeV, but there would be no 1 to 6 MeV electron measurements.

- There would be no measurements of >10 MeV protons for the STEREO Beacon mode.

Although the loss of these measurements would be significant, we believe that their impact on STEREO science would be less than if either LET or SIT were not flown.

Option 3: A New HET Design using Existing Detector Hardware (HET2)

We have a significant number of large-area solid state detectors that are spares from the SIS instrument flown on ACE that could be used in the fabrication of a HET telescope of design similar to that proposed. If these detectors were used, there would be considerable savings in detector design, procurement, and testing, as well as in connector and mounting hardware. Note that the SIS detectors are 65 cm^2 in area, considerably larger than we proposed for HET, and by using correspondingly larger designs for the H1 and H2 detectors we can achieve the same collecting power with a single-ended design. A single-ended design also leads to minor savings in mechanical and electronic parts.

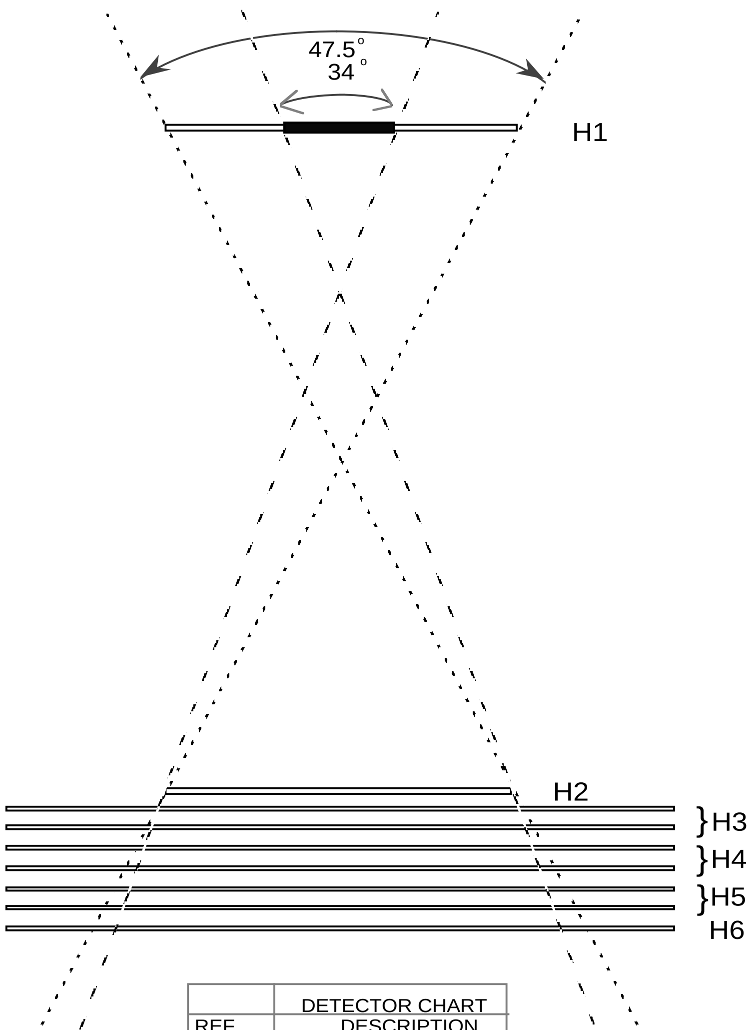
A schematic of the proposed design for HET2 is shown in Figure 3. For energies from 13 to 40 MeV/nuc the response is single-ended (with the telescope oriented along the nominal Parker spiral direction, at ~45° to the Sun). For energies >40 MeV/nuc H and He are identified by the rate at which they lose energy in detectors H1 through H6 (using their Bragg curves, an approach used previously on IMP-8 and Voyager, for example). This penetrating-mode response is actually double-ended; backward-moving particles (40 to ~100 MeV/nucleon) can be identified because their rate of energy loss will increase towards the front of the stack. Although the total thickness of silicon in this design is less than that in the original HET we believe that the HET2 design is adequate to measure solar proton and He energy spectra with energies up to 100 MeV/nucleon, with integral fluxes >100 MeV/nucleon. The electron response will extend from ~1 to ~5 MeV.

The total additional funding needed to implement this option is estimated to be RY $380K. Although the larger area of the SIS detectors will lead to an estimated increase in mass of ~0.4 kg, we do not anticipate any other issues accommodating HET2 on the spacecraft as it can be designed to have the same field of view as the original HET, and it will draw essentially the same power.

One distinct advantage of this option is that it reduces risk. Solid state detectors are always a long-lead item that can affect schedule. With the ACE detectors already in hand, there will be one less item that can potentially lead to delays.

3. Resource Estimates

Table 2 summarizes the proposed and most recent Phase-A estimates of the resource requirements for the SEP system. Phase-A activities over the past few months have led to improved designs for both LET and HET and have provided more reliable (although not yet final) estimates of the mass and power required. Table 2 summarizes both the proposed and the latest Phase-A estimates for the SEP system. The small increases in power in LET and HET are due partly to our choice of a more conservative VLSI design that has somewhat fewer channels per chip than originally assumed. This has resulted in the need for somewhat more chips and correspondingly larger PC boards. These VLSI designs, to be used in LET, HET and SIT, are now well along.



REF.	DETECTOR CHART DESCRIPTION
H1,H2	16 cm^2 x 1.0 mm
H3-H5	65 cm^2 x 2.0 mm
H6	65 cm^2 x 1.0 mm

HET2 ~ High Energy Telescope

Figure 3: Proposed design for the HET2 telescope. The devices used for H3 to H8 would be large-area (65 cm^2) spare detectors from the SIS instrument on ACE. The geometry factor of the above design is 2.2 cm^2sr for proton and He energies from 13 to 40 MeV/nucleon and 4.4 cm^2sr for energies > 40 MeV/nucleon.

In our Phase-A studies we have also learned that in order to make accurate flux measurements during the largest solar particle events it is necessary to instrument the L1 and H1 detectors with a smaller-area, “bulls-eye” region that is used during high-flux periods. This can be accomplished using existing detector designs, but does lead to small mass and power increases because of the additional signals. This approach will ensure that the dynamic range of LET and HET will accommodate both quiet-time and the largest solar particle events.

Table 3 summarizes the resource requirements for the three HET options. All cost estimates include the L2 and L3 detectors for LET and the SEP bias supply. Note that there is a mass increase incurred in using the SIS detectors (and their existing mounts) because of their larger area, and the correspondingly larger housing.

Table 2: SEP Mass, Power, Bitrate Summary

	Mass (kg)		Power (W)		Bitrate (kps)	
Sensor	1999 IMPACT Proposal	Phase-A Estimate	1999 IMPACT Proposal	Phase-A Estimate	1999 IMPACT Proposal	Phase-A Estimate
SEPT	0.70	0.94	0.60	0.60	30	30
SIT	0.78	0.93	0.55	0.66	60	60
LET	0.44	0.51	0.12	0.18	80	80
HET (orig.)	0.27	0.33	0.04	0.07	30	30
SEP Common	1.17	1.67*	0.67	1.39*	0	0
Total	3.36	4.38	1.98	2.90	200	200

*Now includes a low-voltage power supply previously book-kept elsewhere in IMPACT

Table 3: HET Resources

Option*	Mass (kg)	Power (W)	Bitrate (bps)	Additional Cost (RY$K)
HET As Proposed				
1999 Proposal	0.27	0.04	30	0
Phase-A Est.	0.33	0.07	30	730
No HET	0	0	0	0
HET2	0.7	0.07	30	380

* All options include the LET L2 and L3 detectors and the bias supply

4. Summary

The unfortunate loss of the Waseda University contribution to the SEP/IMPACT collaboration makes it impossible to provide all three of the proposed SIT, LET and HET sensors unless additional resources are obtained. To provide the HET sensor as originally proposed requires an additional $730K in funding. If no HET sensor is provided we can afford to provide the SIT and LET sensors, but important high-energy measurements from HET will be missing. These measurements could be provided by a new HET design that makes use of existing detectors from ACE at an estimated cost of RY $380K This appears to us to be a very reasonable approach to mitigate the loss of the Waseda University contribution if the necessary funds can be made available.

In summary, the SEP team favors building the original HET design, as proposed, if the necessary funding is available, but we have identified a low-cost option that meets all of the requirements, which would be our strong second choice. We do not favor eliminating HET because of the important high-energy measurements that would be missed.

Until this matter is resolved, the present uncertainty in the design of the SEP package will continue to impact our efforts during Phase-A, costing valuable schedule time and manpower. It is therefore desirable to decide between these or any other options as soon as possible. We would welcome the opportunity to discuss these options in person with STEREO Project Management to help resolve any questions or issues in a timely manner.