C. IMPACT Instrumentation

C.1 System Design

C.1.1 Design Overview

The STEREO IMPACT Suite consists of a set of seven instruments plus a common Instrument Data Processing Unit (IDPU), as shown in Figure C.1-1. They have a single C&DH system interface via the IDPU, and a single Project interface through the PI and Project Manager.

C.1.1.1 SEP Package

The SEPT, SIT, LET, and HET instruments together form the SEP subsystem. They are co-located except for the SEPT-NS head, which was split off during Phase A to provide a better Field of View. In this document, we refer to the part of SEPT, in the SEP package box as SEPT-E, and the separated part as SEPT-NS. The SEP subsystem shares a common processor that controls the SEP instruments, formats their data, and interfaces with the IDPU. The IDPU acts mostly as a bent pipe for SEP commands from and telemetry to the spacecraft.

Note that since the proposal, our CoI at Waseda was unable to get funding, which compromises the HET instrument. Appendix F discusses three ways to deal with this situation. In this proposal we have assumed the compromise, lower-cost, higher-weight solution is selected by the project.

C.1.1.2 Boom-Mounted Instruments

The MAG sensor, SWEA, and STE instruments are all mounted on the IMPACT boom (MAG to get

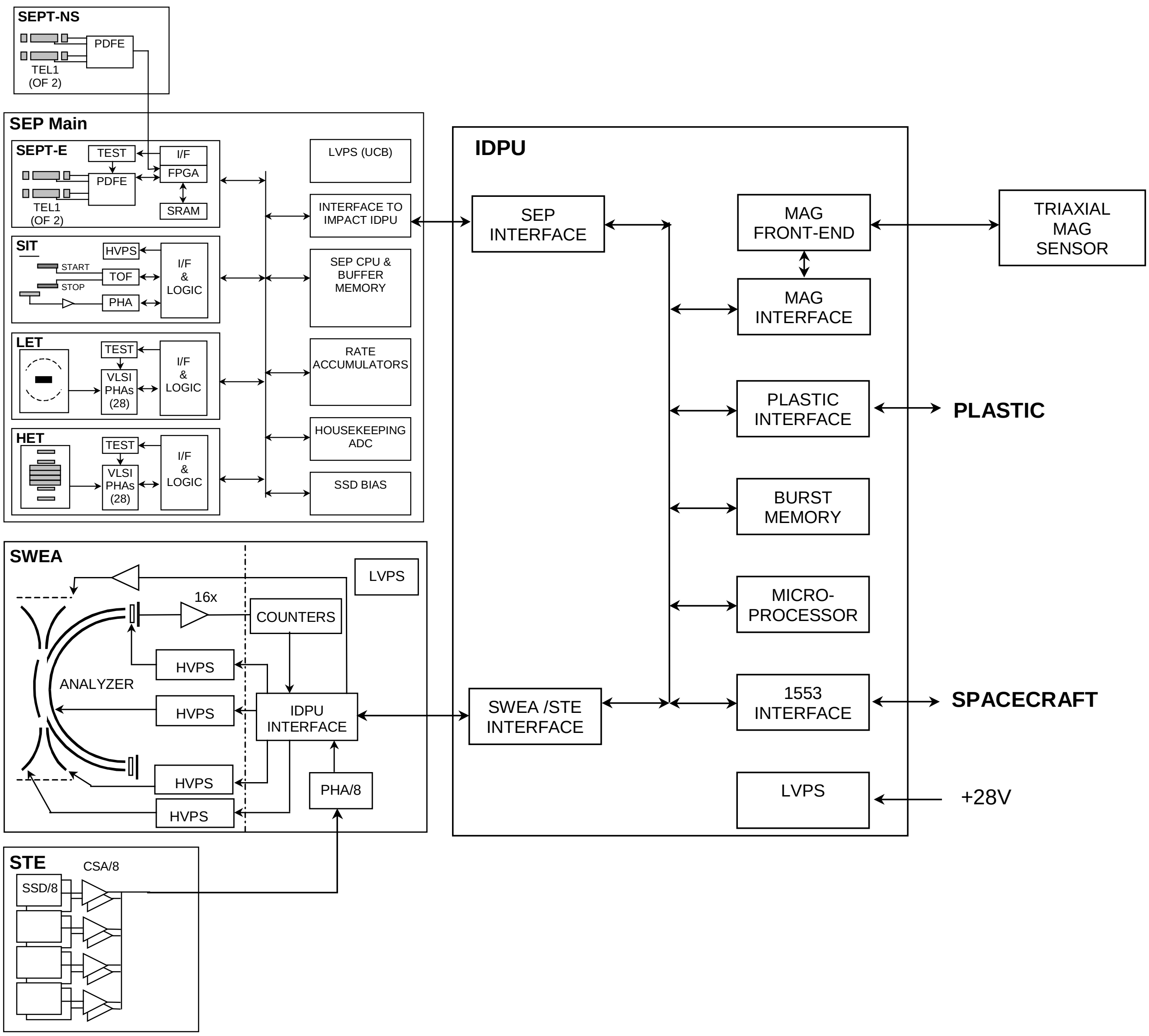

Figure C.1-1 IMPACT Block Diagram

separation from spacecraft-generated fields, STE to facilitate passive cooling, and SWEA to accommodate its large FOV). In addition to the instruments, the boom itself is now part of the IMPACT responsibilities. The MAG front-end electronics are housed in the IDPU. STE contains only its preamps locally, with the remaining front-end electronics housed in SWEA to minimize power dissipation in STE. SWEA includes all its front-end electronics through the accumulators. SWEA and STE communicate with the IDPU over a common digital serial interface. Unlike the SEP instruments, the IDPU controls the boom-mounted instruments directly, and collects and formats their data. SWEA and STE will operate automatically based on mode information loaded by the IDPU over the serial interface, relieving the IDPU of repetitive control tasks.

C.1.1.2.1 Boom System. The boom system consists of a fixed mast section on which the SWEA, STE and MAG are mounted, and an Astromast section that interfaces with the fixed mast and the spacecraft. In this document, the term “boom” refers to both, “fixed boom” refers to the section on which the instruments are mounted.

C.1.1.3 PLASTIC Interface

In addition to the IMPACT instruments, the IDPU also services the PLASTIC instrument. The PLASTIC instrument includes its front-end electronics up through the accumulators and instrument control functions, similar to the SWEA/STE instruments. The PLASTIC control/accumulation/formatting software for the IDPU will be developed at UCB with input from the PLASTIC team in the form of requirements documentation, a PLASTIC simulator to aid software testing, and several IDPU to PLASTIC hardware/ software interface tests.

C.1.1.4 IDPU

The IDPU provides a controlling element for the IMPACT suite and PLASTIC, and serves as the single interface for these instruments to the spacecraft C&DH system. The system includes a modest 16-bit microprocessor and supporting hardware, a 2Mbyte burst memory to capture fast event data, a 1553 interface to the spacecraft, and serial interfaces to the instruments. The IDPU connects to the instruments over a three-wire bi-directional serial interface. Identical serial interfaces go to SEP, SWEA/STE, PLASTIC, and internally to the MAG analog front-end card.

The IDPU has no field-of-view issues, and so can be mounted internally to the spacecraft, and can be thermally coupled to the bus for ease of thermal design.

C.1.1.5 Low Voltage Power Supplies

IMPACT uses separate low voltage power supplies (LVPS) for the IDPU/MAG, SEP, and SWEA/STE. The spacecraft supplies separately switched and protected services directly to these units. Separate supplies improves reliability, minimizes EMI, and eliminates the need for limiting and switching in the IDPU. These supplies, along with the PLASTIC LVPS, shall be developed together at UCB with a common design to minimize the development effort.

C.1.1.6 SWAVES Interface

IMPACT and SWAVES shall communicate burst trigger information via the spacecraft 1553 interface using RT to RT transfers. This avoids requiring a separate hardware interface and harness for this exchange. The Spacecraft contractor has agreed to facilitate this exchange on a regular basis (5 exchanges per second).

C.1.1.7 Spacecraft Interface

The IMPACT spacecraft interface requirements are called out in detail in Appendix A of this document, and summarized here.

The interface with the C&DH system is via a 1553 interface to the IDPU. This interface services both IMPACT and PLASTIC. This interface provides command, telemetry, spacecraft and instrument status, and timing exchanges as specified in the Spacecraft/Investigation ICD (Draft 1.3). Note that while the timing provided over this interface will be used for time-stamping telemetry packets, instrument sampling will be based on an internal clock.

Spacecraft unregulated 28 volt power will be provided over separately switched and protected services to the IDPU, SEP, and SWEA/STE. In addition, survival heater services are required. These heaters shall be thermostatically controlled, and so will consume only the power required to keep the instrument above the lower survival limit. A special electronic thermostat (in the IDPU) is required for the MAG sensor, since a mechanical thermostat would be too magnetic.

After some iterations with the spacecraft and modifications to our instruments we have mostly cleared the instrument FOV, with some exceptions as called out in the instrument sections below.

C.1.1.8 Beacon Mode Telemetry

Table C.1-1 summarizes the beacon mode telemetry generated by the IMPACT and PLASTIC suites, and provided to the spacecraft over the 1553 interface. The data rate is consistent with about one packet per minute. The rate has increased significantly since the proposal to improve science return and to increase the packet transmit rate given the fixed packet size. Beacon data is also sent via the normal telemetry stream so that gaps may be filled in once the recorder data is available.

Table C.1-1 STEREO IMPACT & PLASTIC Beacon Mode Telemetry

Instrument	Measurement	bps
SEP-SIT	He, 2E	0.53
	CNO, 2E	0.53
	Fe, 2E	0.53
SEP-SEPT	Electrons, 3E	0.80
	Ions, 3E	0.80
SEP-LET	Protons, 1E	0.27
	He, 1E	0.27
	CNO, 2E	0.53
	Fe, 2E	0.53
SEP-HET	Electrons, 1E	0.27
	Protons, 3E	0.80
	He, 1E	0.27
MAG	1 Vector	0.80
STE	2 directions, 3E	1.60
SWEA	Moments	8.00
PLASTIC	SW Proton Moments	1.33
	SW Alpha Density	0.27
	SW Charge State	1.33
	Suprathermal, 2E/Q*3Z*5A	8.00
Instrument Status		0.53
Packet Overhead		1.60
TOTAL		29.60

C.1.2. IMPACT Resource Requirements

Table C.1-2 summarizes the IMPACT instrument resource requirements. These are the Current Best Estimates, with no implementation margins added (margins are currently held by Project). There are a number of important caveats to this table:

1. The SEP and SEPT-NS bracket masses are conservative estimates by the IMPACT team. APL estimates are somewhat lower (0.76kg and 0.10kg). Neither estimate has much analysis behind it, so we prefer the more conservative estimates. In any case, the spacecraft configuration is still in the process of change. Better bracket weights can be assigned once the spacecraft is stable and an analysis has been done.
2. The harness mass does not include the harness up the Astromast section. The indicated boom mass does not include the Astromast, only the fixed mast. The Astromast plus harness and caging mechanism have a separate allocation of 12kg. Other configurations of this mast are under consideration - see section C.2.4.
3. No operational heaters have been base-lined. We hope to be able to keep the instruments within their thermal limits passively. This needs to be analyzed in Phase B. For now this is an un-sized lien on the power budget.
4. It has been determined that STE and SEPT require in-flight reclosable covers. The mass of these cover mechanisms has not been included. Early analysis indicates a low mass solution (~30g/cover, 100g total) might be possible.
5. The HET mass indicated is that required for the proposed compromise implementation. Since we lost the Waseda contribution to the HET instrument, we have an alternative design using existing detectors with cost savings but some mass penalty (see Appendix F of this report).

The resources in Table C.1-2 are above the proposal numbers (minus the descoped 3DC instrument) due to a number of factors:

1. The fixed boom mass was added to the IMPACT allocation.
2. The SEP brackets were added to the IMPACT allocation.
3. The instrument thermal blankets were added to the IMPACT allocation.

Table C.1-2 IMPACT Resource Requirements

Instrument	Mass, kg	Power, W	Bps
SEP:			
SEPT-E	0.46	0.52	120
SIT	0.93	0.66	240
LET	0.51	0.18	320
HET	0.70	0.07	120
SEP Common Elec.	1.49	0.85	
SEP LVPS	0.20	0.70	
SEP Total	3.91	2.99	800
SEPT-NS	0.44	0.52	
SEP-NS Bracket	0.20		
SEP Bracket	1.00		
Boom Instruments			
SWEA (CESR)	1.21	0.54	394
SWEA/STE I/F	0.30	0.30	
SWEA/STE LVPS	0.20	0.26	
STE	0.35	0.20	64
MAG Sensor	0.25		154
Fixed Boom	0.35		
Fixed Boom Total	2.66	1.30	612
IDPU:			
Mag Card	0.30	0.38	
DPU Card	0.30	0.80	
Interface (on DPU card)		1.70	
IDPU LVPS	0.20	0.72	
Mag Heater Control	0.07		
BOX	0.87		
IDPU Total:	1.73	3.60	164
Burst Telemetry			524
Harness	0.64		
Thermal Blankets	0.20		
TOTAL	**11.15**	**8.41**	**2100**
Project Allocation	**10.30**	**7.06**	**2100**

4. A mass penalty was incurred when the SEPT-NS was separated from SEP to clear its FOV. Note that the SEP FOV did not require this separation for the spacecraft configuration in the Announcement of Opportunity we sized the instrument to.
5. The 1553 interface circuit power was transferred to IMPACT. As of the proposal it was not included. Note that 1.5W was transferred, while 1.88W is the current best estimate for this power. The difference is the power supply conversion efficiency, which was not included in the amount transferred to IMPACT for some reason.
6. There have been a number of instances of mass and power redistribution, growth, and even some decreases, as the design has matured through Phase A.
7. The instrument telemetry allocation was increased substantially by Project in response to a request by the IMPACT team. This increase reduces the amount of telemetry compression required in the IDPU, improves the throughput for ground testing, and improves science return, while having minimal impact on the spacecraft.

The mass and power resources in Table C.1-2 are also above the current Project allocations. The mass difference is primarily due to the difference between the APL and IMPACT estimates of the SEP and SEPT-NS bracket and the assumption that we use the heavier compromise HET. The power growth is partly due to an incomplete allocation for the 1553 bus. The remainder is due to increases in the SEP power consumption estimates. This growth is due to the normal process of design maturation rather than any extra science requirements. We have made every effort to reduce the power, eliminating excess instrument performance above what is required to make the measurements promised in the proposal. The only way we can see to reduce the power further, short of descoping an instrument, would be to power-cycle some of the instruments. For example, an instrument that generates data once a minute might be on only 30 seconds of that time. This adds some complication to the instruments, and perhaps a little mass for the power switches. It also eliminates the continuous time coverage, since instruments will be off some of the time, and reduces counting statistics. These are serious science losses, and we strongly encourage Project to try to find the extra power required. We assume this will be worked further in Phase B.

C.1.2.1 IMPACT Power Profile

During commissioning, the IMPACT power usage will gradually step-up as each instrument is turned on (with associated short in-rush current spike). These increase will be partially offset be associated decreases in instrument heater power. The sequence of instrument turn-on has yet to be determined, and so the timing of the power profile is uncertain. Once powered up, IMPACT will consume the average power indicated in Table C.1-2. During some maneuvers, at least part of the IMPACT suite will be powered off creating an temporary decrease in the power profile, partially offset by increased heater power. Above this average power level, IMPACT makes three kinds of peak power:

1. Current ripple; cyclic current peaks with periods on the order of seconds or less. It is driven by instrument accumulation cycles, high voltage sweeps, and 1553 traffic. The amplitude of this ripple is typically 10-20% of the average power.
2. Rate-driven power increases. When the instrument count rates go up, the power consumption rises. The rate rarely goes up enough to be significant, but on rare occasions may go us as much as 1W for several hours (for a large solar event or magnetosphere region).
3. Operations-driven power increases. For IMPACT, other than the instrument power switching described above, the only items that fall into this category are cover openings:
   a. The SWEA cover needs to be opened one time, as soon as possible, but no sooner than 1 day after launch to allow time for spacecraft out-gassing. The currently planned cover actuator requires about 50mA on 28V for 20 seconds.
   b. The SIT cover is also a 1-time opening cover that will be opened early in the commissioning phase. An actuator has not been selected for this cover.
   c. The STE cover is required to avoid contamination of the very sensitive detector by hydrazine thrusters. It will need to be actuated to open the detector early in the commissioning phase, then again just before and just after each thruster firing. We may also want to close the cover to avoid direct, continuous sunlight on the detector to avoid overheating. The actuator for this cover is under development, but is expected to take on the order of 1 amp of 28V for perhaps tens of seconds.
   d. The SEPT covers have similar requirements to that of STE, though sunlight is probably the primary concern. They will cycle the same was as the STE covers. The actuators for this cover have not yet been selected.

C.1.3 Instrument Suite Development and Integration

Pieces of the IMPACT instrument suite are developed at a large number of institutions around the world. Appendix G shows who is responsible for each part of the instrumentation. Interfaces between the various pieces shall be controlled by a series of Interface Control Documents (ICD) to be developed early in Phase B. These ICDs shall also include functional requirements as appropriate to ensure that the systems will work together.

To aid in development, interface simulator GSE shall be developed for the more complicated interfaces. For example, UCB shall develop an IDPU simulator for use by the instrument developers. This GSE shall verify the interface characteristics of the instrument, and also allow the instrument team to operate their instrument in the absence of the IDPU. This GSE shall be developed in Phase B and provided to the appropriate instrument teams (including PLASTIC) so it can be used during Engineering Test Unit (ETU) testing.

Most of the IMPACT hardware, including all of the electronics, shall first develop an ETU to verify the design and interfaces. Around the time of the CDR these ETU shall be brought together to verify the interfaces directly.

Flight unit fabrication shall be subject to the Performance Assurance Requirements called out in the IMPACT Performance Assurance Implementation Plan (PAIP) included as Appendix B of this document. Preliminary contamination Control, Configuration Management, and Safety plans are called out in Appendix C, D, and E respectively.

The flight units shall come together for an early interface test, perhaps before some of them are calibrated. During this test, the flight software compatibility shall be verified as well as the other interfaces. At this time or some later time the instruments need to come together for the EMC tests. Vibration and Thermal Vacuum shall be done at the subsystem level (SEP, SWEA, STE, Mag sensor, Boom, IDPU), since they see such different environments. They then come together one more time shortly before delivery to the spacecraft for a final pre-delivery functional test.

Once delivered to the spacecraft, testing shall be supported by a subset of the team. Team members will be cross-trained on the various instrument test procedures so that only a few team members need be present at testing. For commissioning, this core team will be supplemented with instrument specialists. We will try to phase the instrument commissioning to one instrument at a time actively commanding the suite to avoid too many people at the SCC and resulting confusion. Instrument accomodation requirements during integration are called out in appendix A.

Details of the development process for each instrument are somewhat different and more fully described in the instrument sections, C.2-C.4.

C.1.4 Changes from the proposed IMPACT Instrumentation

There have been many changes to the IMPACT suite since the proposal. They are itemized here, and discussed in more detail in the following sections. These changes are sufficient in scope to make it somewhat difficult to compare the development effort and resource requirements of the proposed IMPACT suite with the current implementation.

1. The 3DC ion analyzer was descoped from the IMPACT suite at the time of selection. The associated mass, power, and dollars were also removed from the instrument resource allocations.
2. Addition of the PLASTIC ion instrument to the IDPU clients. The IDPU is now connected to the PLASTIC instrument via a serial digital interface, and fills the processing needs of the PLASTIC instrument as well as serving as the interface to the spacecraft for commands and telemetry.
3. As mentioned in the proposal, SWAVES and IMPACT would benefit from the ability to exchange information on-board. This has been accommodated via the spacecraft 1553 interface without need of a dedicated interface circuit and harness.
4. The SEP Fields of View have been very difficult to accommodate on the current spacecraft (they were more easily accommodated on the spacecraft design referred to in the Announcement of Opportunity). This has involved a number of reconfigurations of SEP, including the separation of the SEPT-NS sensor from the rest of SEP, and special bracketry to hold SEP and SEPT-NS away from the spacecraft. The SEP instrument configurations are also no longer identical on the two spacecraft, adding complexity to the development effort.
5. Our Co-Investigators at Waseda were unable to get funding to provide hardware for the STEREO instrument. This has resulted in a proposal to STEREO Project to provide a NASA-funded HET instrument. A few options are provided with different capabilities, resource requirements, and cost. A copy of this proposal is attached as Appendix F of this document. This issue is still open.
6. Responsibility for the IMPACT boom, including the fixed mast and the depoyable Astromast, has been transferred to the IMPACT team (UCB).
7. Addition of in-flight reclosable covers for STE and SEPT. The requirement for these covers comes out of preliminary studies done in Phase A of thruster contamination and exposure of detectors to sunlight. We have not yet completed designing these covers, and so have only preliminary estimates of their resource requirements.
8. The Low Voltage Power Converter design was changed from a single common supply to a set of smaller converters mounted in the instrument suites (IDPU/MAG, SEP, SWEA/STE). This improves reliability, and minimizes EMC concerns with minimal resource impact. This change resulted in some redistribution of mass and power dissipation amongst the instruments.
9. The SEPT design was modularized. This was partially driven by the separation of SEPT-NS from

the rest of SEP. This results in an easier to fabricate and test instrument, but with some resource impacts (as described in section C.1.2 and C.3.2).

10. As much as possible of the STE electronics has been moved to SWEA to minimize the power dissipation in STE and to share resources with SWEA.
11. The SIT TOF system development was a shared development with the 3DC instrument. MPAe has agreed to continue development of this system for the SIT instrument alone. Similarly, the SIT High Voltage Supply was part of a common design with 3DC at UCB.

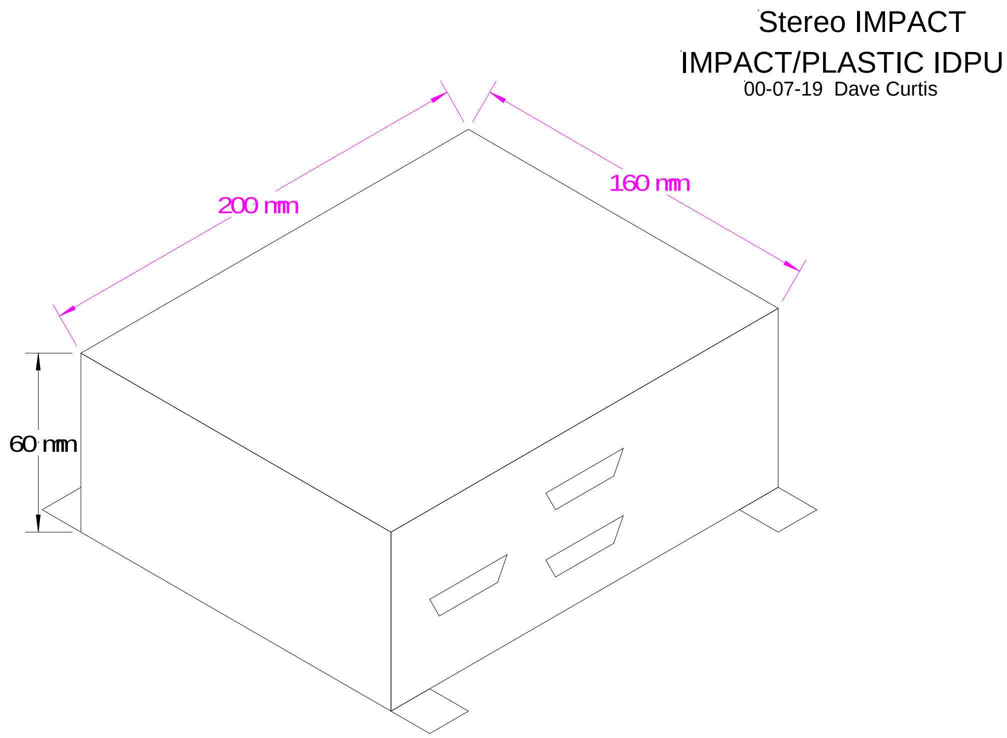

Figure C.1-1 IDPU

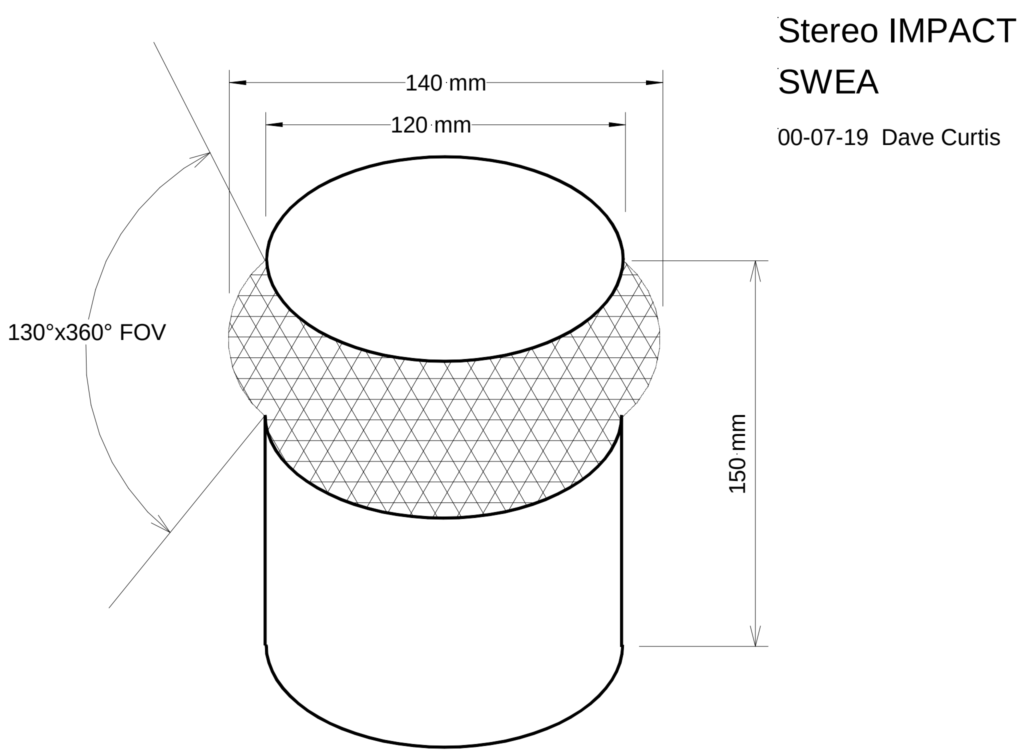

Figure C.1-2 SWEA

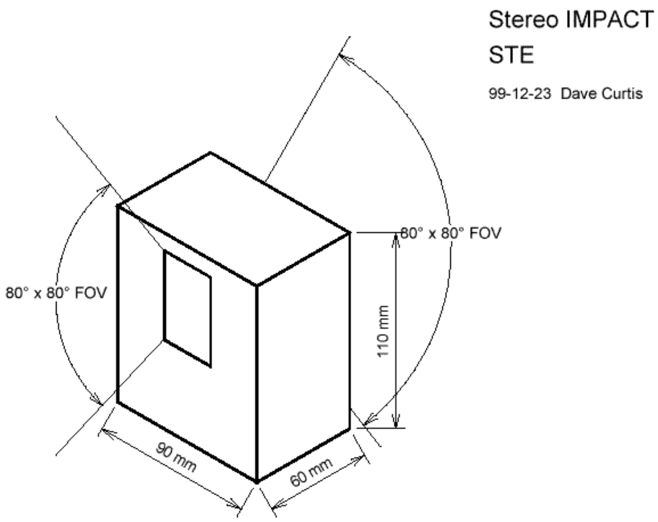

Figure C.1-3 STE

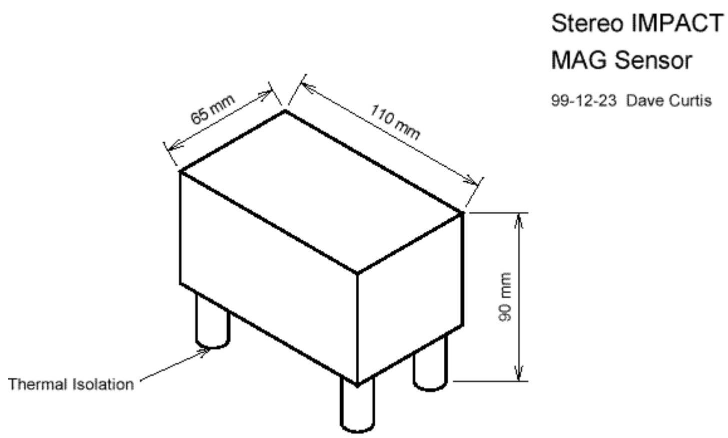

Figure C.1-4 MAG Sensor

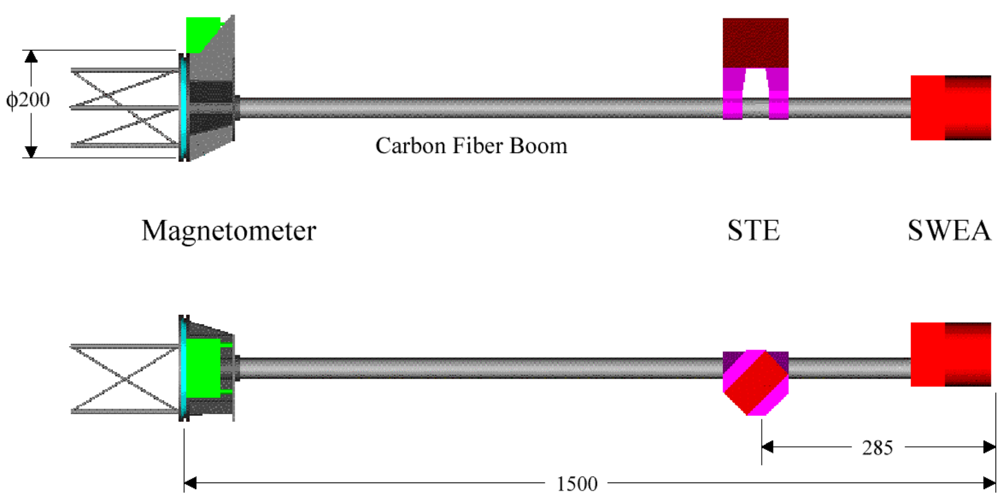

Figure C.1-5 IMPACT Fixed Boom

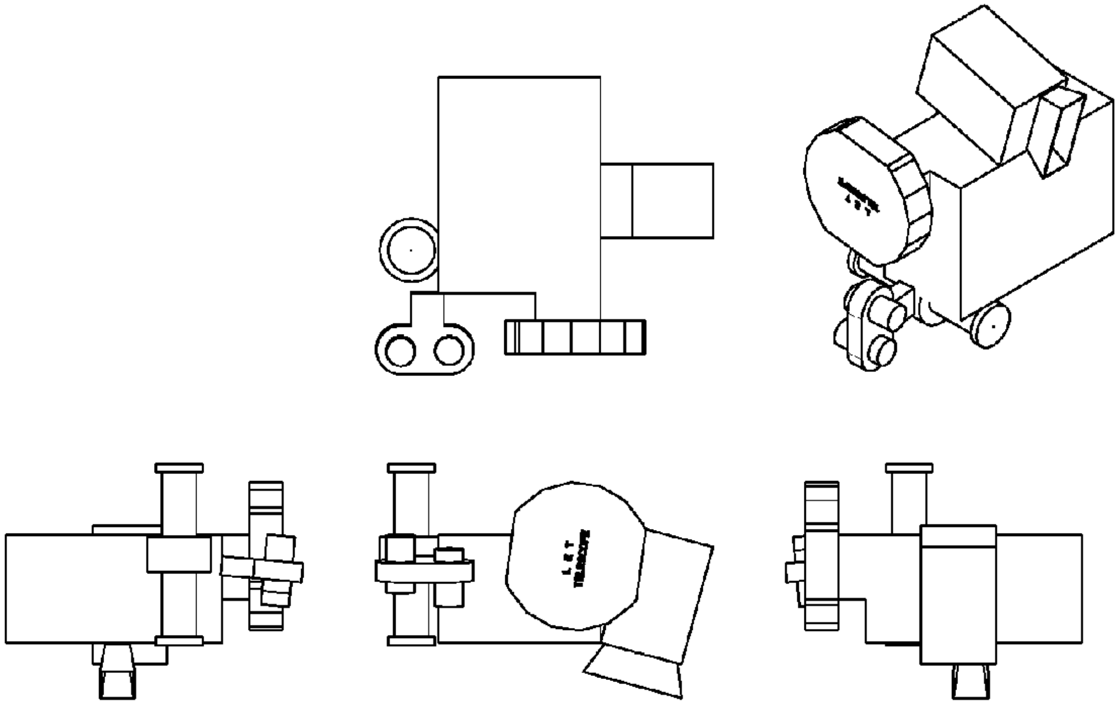

Figure C.1.6 Leading Spacecraft SEP configuration

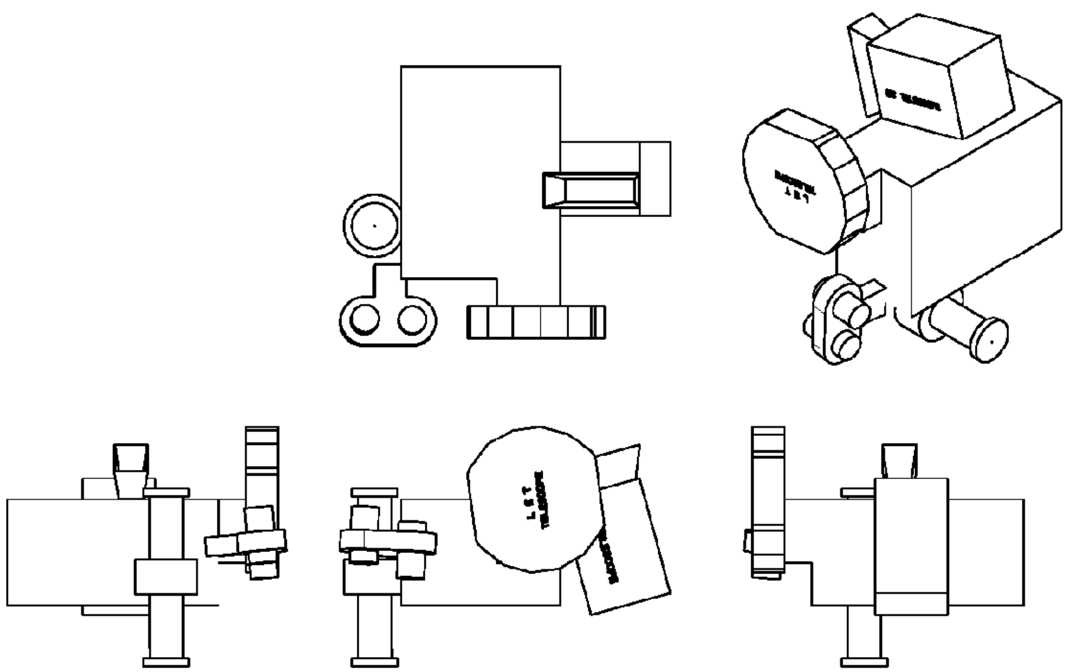

Figure C.1.7 Trailing Spacecraft SEP configuration

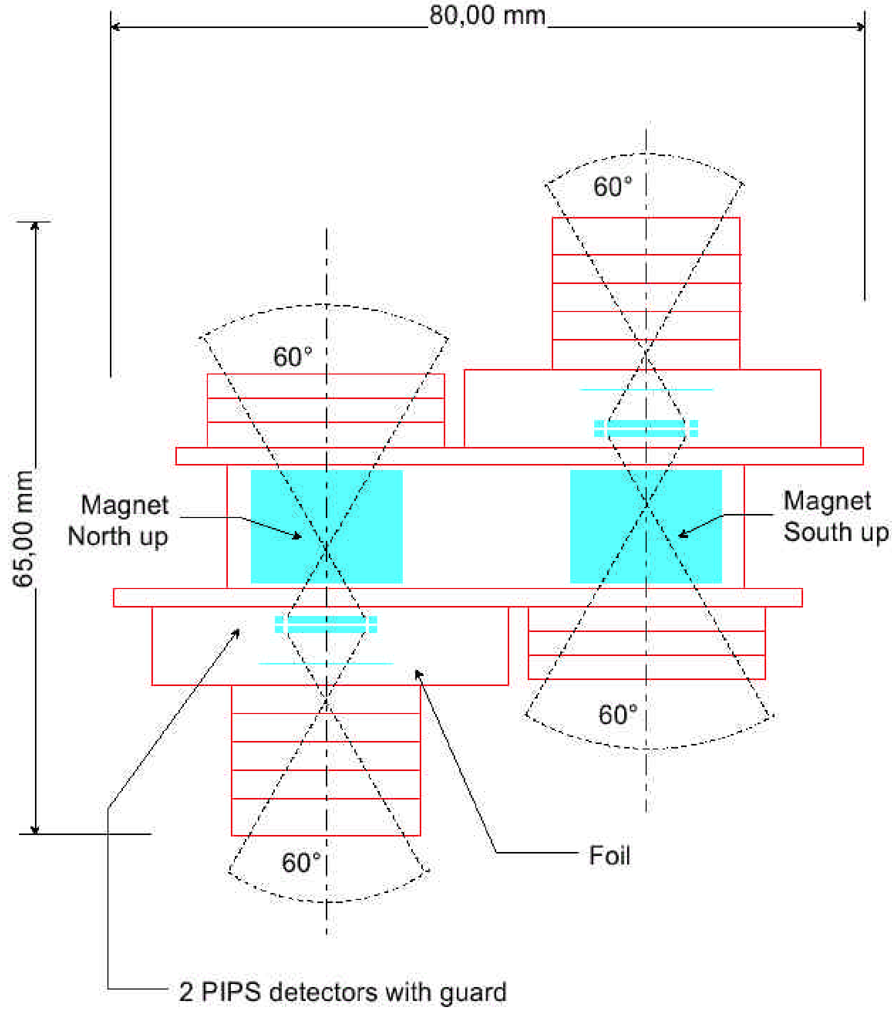

Figure C.1.8 SEPT-NS