Stereo IMPACT Instrument Requirements for the Spacecraft
Dave Curtis 2000-July-19

This document provides a single point for all STEREO IMPACT instrument requirements on the Spacecraft. It is assumed that most if not all of these requirements will find their way into the Spacecraft to Instrument ICD. However, since not all IMPACT CoIs have access to the ICD at this time, and because the ICD is still in early phases, this document is being used to document and coordinate these requirements.

These requirements are based on the current spacecraft design as described in the Draft Interface Control Document, version 1.3 (ICD), and other spacecraft design documentation as called out. If significant changes are made in the spacecraft design, some of these requirements will need to be renegotiated.

Spacecraft Interfaces:

1. C&DH
    1.1. 1553 Interface
    The IMPACT/PLASTIC IDPU requires one interface as described in the ICD. This will be the only interface required for instrument commands, telemetry, timing, and status as described in the ICD for both the IMPACT and PLASTIC instruments
    1.2. SWAVES Interface
    In addition to the services described in the ICD, we would like to use the 1553 bus to pass information between the IMPACT/PLASTIC IDPU and SWAVES. The baseline requirement is that we pass two word messages each direction four times a second. If this scheme is rejected, a separate harness between SWAVES and the IMPACT/PLASTIC IDPU will be required.
    1.3. Timing
    The 1553 timing interface described in the ICD and further detailed in the "Timekeeping presentation from coordination mtg 3/30/00" shall be adequate.
    1.4. Telemetry Packets
    The IMPACT/PLASTIC IDPU shall provide telemetry in the form of CCSDS source packets as described in the ICD. A block of at least 100 packet Application ID numbers should be reserved for IMPACT/PLASTIC telemetry. IMPACT/PLASTIC telemetry packets headers shall include a packet collect time based on the UTC spacecraft clock provided over the 1553 bus, though data will be sampled based on an internal clock. This will require some small margin to our telemetry allocation to account for clock mis-match, as well as oversampling of the instrument "telemetry available" flag.

1.5. Telemetry bandwidth

IMPACT/PLASTIC produce three types of telemetry packets: Normal, Beacon, and Diagnostic. Normal telemetry is the continuous science data stream routed to the recorder and then to the ground during contacts. Beacon data is summary Beacon mode data to be routed directly to the transponder for continuous link to the ground (if anybody is listening). Diagnostic data is for use during I&T and on-orbit diagnostics, to get near-real-time telemetry to the ground. This data is only useful during contacts, and should not be recorded. Diagnostic data is a desire, not a hard requirement. However, without some amount of diagnostic data (or a significantly enhanced bitrate) I&T, LEO checkout, and on-orbit troubleshooting will become difficult and time-consuming. Since this mode is not used routinely, it is not expected to impact downlink requirements.

1.5.1. Normal Telemetry Rate

The average Normal telemetry rate should be:

SEP	800 bps	
SWEA	394 bps	
STE	64 bps	
MAG	154 bps	
Burst	524 bps	
Beacon	32 bps	
Hsk	32 bps	
Pkt Header	100 bps	(includes packet collect time)
Total	2100 bps	

- Note that PLASTIC telemetry allocation is not listed, but PLASTIC data will come through the same interface

- Note that Beacon mode data is included in the normal telemetry stream as well as in the beacon stream. This simplifies filling data gaps in the beacon mode coverage.

1.5.2. Beacon Mode Telemetry Rate

Proposed beacon mode bitrate, including PLASTIC:

SEP	6.13 bps	
SWEA	8.00 bps	
STE	1.60 bps	
MAG	0.80 bps	
PLASTIC	10.93 bps	
Status	0.53 bps	
Spare	2.67 bps	
Pkt Header	1.60 bps	(includes packet collect time)
Total	32.27 bps	One 242-byte packet/minute

1.5.3. Diagnostic Telemetry Rate

This should be no less than the Normal telemetry rate. A significantly higher rate, such as 10kbps, would be desirable.

1.6. Commanding issues

1.6.1. Typical operational requirements

IMPACT requires little commanding during the nominal mission. An occasional mode change or parameter change may require a few commands a week, up to a few commands a day during the early phasing orbits and during rolls.

1.6.2. Commissioning Phase/Diagnostic requirements

For initial turn-on of the instruments as well as for diagnostic trouble-shooting, we require near-real-time commanding. This should be coordinated with near-real-time Diagnostic Telemetry availability (see 1.5.3). At these times we will send tens of commands an hour, with on the order of hundreds of commands required for the first instrument turn-on and commissioning.

1.6.3. Memory load capability

We may rarely need to uplink memory loads consisting of several thousand bytes (I believe as large as a million of bytes for PLASTIC). We will implement a system that allows these loads to be broken into self-contained packet-sized blocks with error checking.

1.6.4. Time-Tagged Commands

Mostly commands will have no time constraints, but occasionally (particularly during the early mission) we may want time-tagged commands to coordinate activities with the orbit or between the two spacecraft. These can use a spacecraft time-tagged command facility, or we can implement a time-tagged command processor in the IDPU (TBR). Time-tagged commanding requirement for IMPACT will not exceed 1kbyte/day.

1.7. Temperature Sensors

The IMPACT instrument consists of the following boxes:

IDPU
SEP
SEPT-NS
SWEA
STE
MAG

At least one spacecraft temperature sensor should be in each box. SEP may require more than one sensor given its complex configuration (TBR). The signals for these sensors can either be routed to the IDPU, or to the individual boxes (preferred) (TBR)

1.7.1. MAG Thermistor

The spacecraft temperature sensor for the MAG sensor may be a problem magnetically (TBR).

2. Power

2.1. Instrument Power

28V instrument primary power as described in the ICD (Main power bus) is adequate for IMPACT. IMPACT has 3 separate instrument power inputs: one for the IDPU and MAG, one for

SEP, and one for SWEA/STE. We desire these services to be separately limited and switched by the spacecraft to improve reliability (particularly since the IDPU also services PLASTIC) (TBR)

2.2. Operational Heaters

We currently expect to need no operational heaters, with the possible exception of SEP, SWEA, and the MAG sensor (see Thermal Requirements below). We have budgeted no operational heaters (TBR).

2.3. Survival Power

When the instruments are powered off, they will need a TBD power level for survival heaters. We expect that these will be thermostatically controlled, with the thermostat set to the survival temperature level. In principal we need one survival power circuit for every instrument power service, but we can probably live with one service that comes on when any of the instrument power services turn off. Because the thermostats will be set so low, we should not take any survival power for any part of the instrument that remains powered while the spacecraft is in nominal attitude. We would prefer a single Survival Power service that is always on, even when the instrument is on. The IDPU may not need a survival heater since it is thermally coupled to the deck (TBR).

2.3.1. MAG Survival Heater

The MAG cannot have a standard thermostat nearby (magnetically hot materials and intermittent DC current). A closed-loop control circuit will be provided to modulate the MAG Survival heater.

2.4. Pyro Power

2.4.1. SWEA/SIT Covers

SWEA and SIT have one-time deployable covers. The actuators required to open these covers have not been identified. If they take significant power, we will want to fire these covers with spacecraft pyro circuits (TBR). Some possible actuators take several seconds of power to actuate; is this possible with a pyro circuit? The SWEA cover should probably be powered off the SWEA/STE power service to avoid another pair of wires up the boom (TBR)

2.4.1.1. STE, SEPT Covers

These apertures also need reclosable covers to protect the detectors from contamination from thruster firings and sunlight in off-nominal spacecraft attitudes. The STE cover actuator should probably be powered off the SWEA/STE power service if possible to avoid another power harness up the boom (TBR).

2.4.2. SWEA/STE/MAG Boom Caging Release

The boom caging system will require a TBR actuator to release the boom prior to deployment of the deployable boom (astromast). Power for this actuator shall come from a pyro circuit. This power can be routed directly to the caging mechanism. It is expected that the firing circuit and any status switch monitors are provided by the spacecraft.

2.5. Power Routing

Power can either be delivered to the IDPU, or directly to the subsystems (preferred) (TBR).

2.6. Average Power Consumption (Current Best Estimate, as of 2000-July-19, no margin included, no operational heaters):

SEP	3.48 W
SWEA/STE	1.30 W
IDPU/MAG	3.60 W
Total	8.39 W

2.7. Peak Power

2.7.1. Inrush Peak Current

During turn-on of the Instrument power services, the inrush current shall be less than 7 amps in the first 200 ms (ICD v1.3 section 2.3.1).

2.7.2. Operational Peak Current

There are 3 components to the 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. Event-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 1-2W for several hours (for a large solar event or magnetosphere region).
3. Special mode drive power increases. For IMPACT, 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 outgassing. 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.

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3. Mechanical (interface)

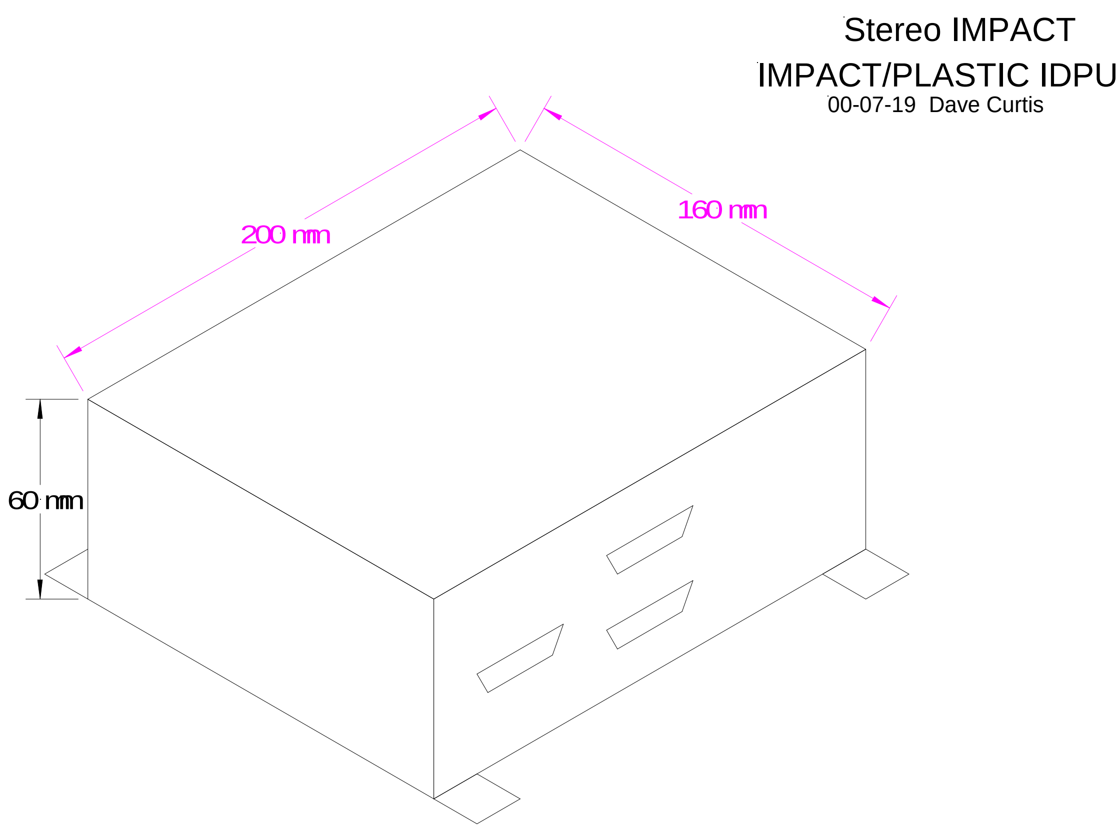
3.1. Mass (Current best estimate, 2000-July-19, no margin included):

SEP-MAIN	3.83 Kg	
SEPT-NS	0.44 Kg	
SEP Bracket	0.76 Kg	(APL Estimate)
SEPT Bracket	0.10 Kg	(APL Estimate)
SWEA	1.71 Kg	
STE	0.35 Kg	
MAG	0.25 Kg	
BOOM	0.35 Kg	
Harnesses	0.64 Kg	
Blankets	0.20 Kg	
IDPU	1.73 Kg	
Total	10.36 Kg	(+TBD)

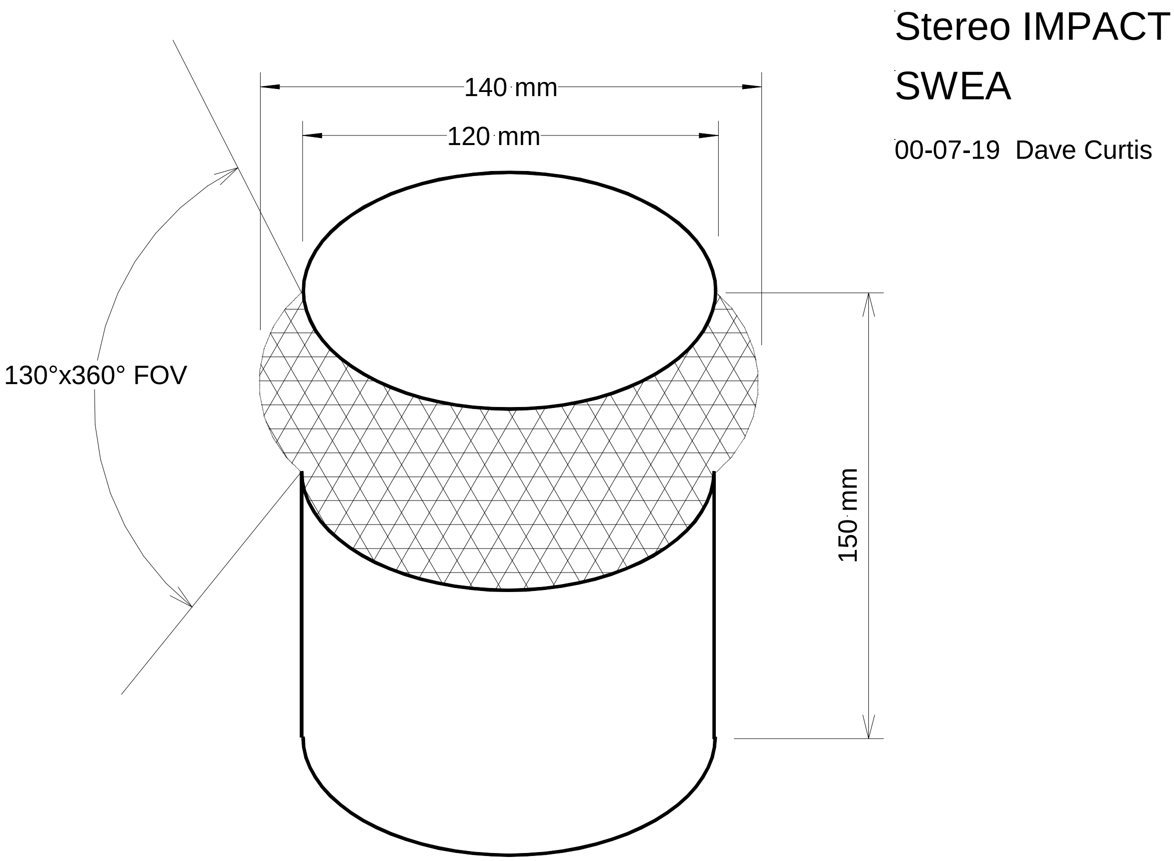
The Astromast, including harnessing and caging, is separately budgeted. Current allocation is 12Kg.

3.2. Envelope

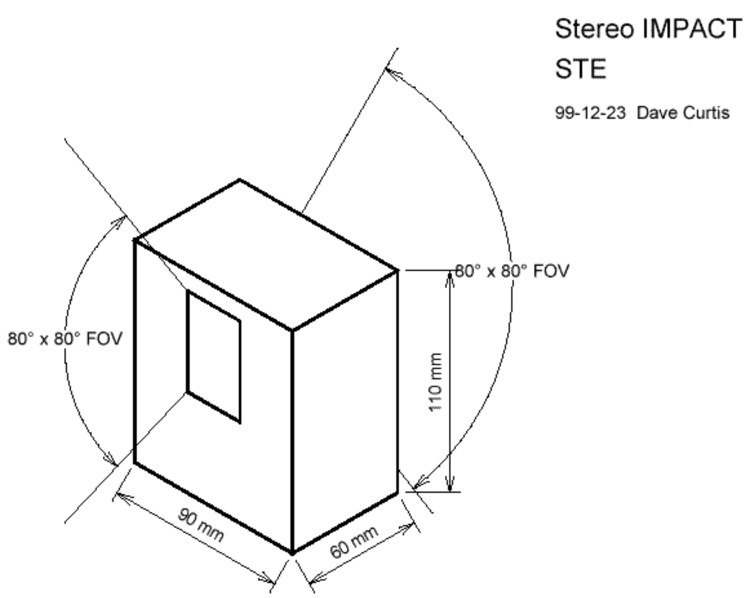
3.2.1. IDPU



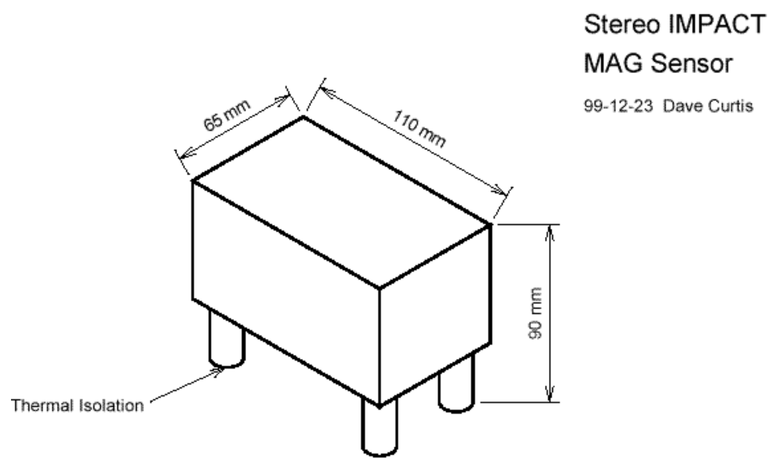
3.2.2. SWEA



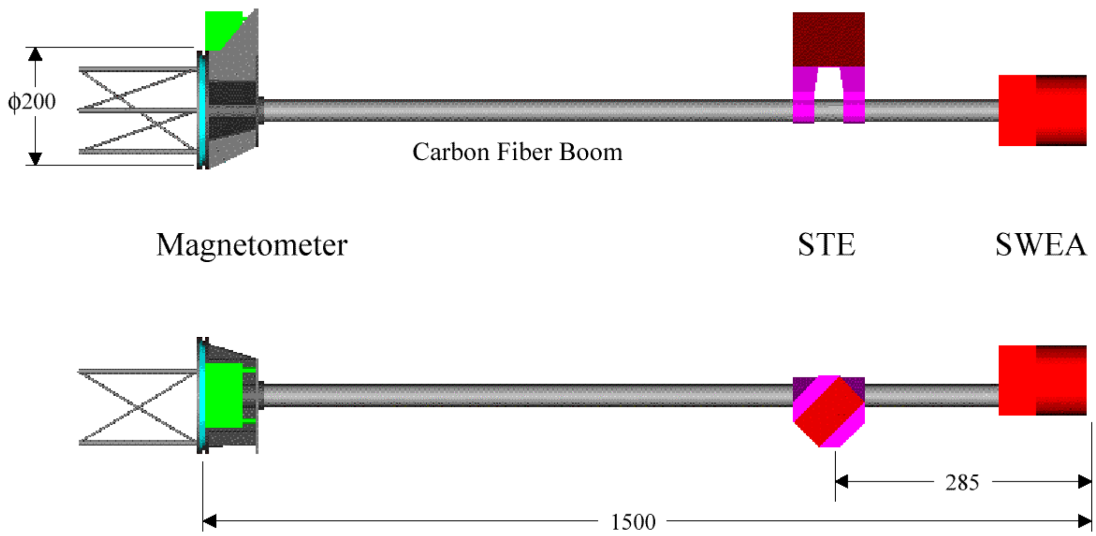
3.2.3. STE



3.2.4. MAG sensor



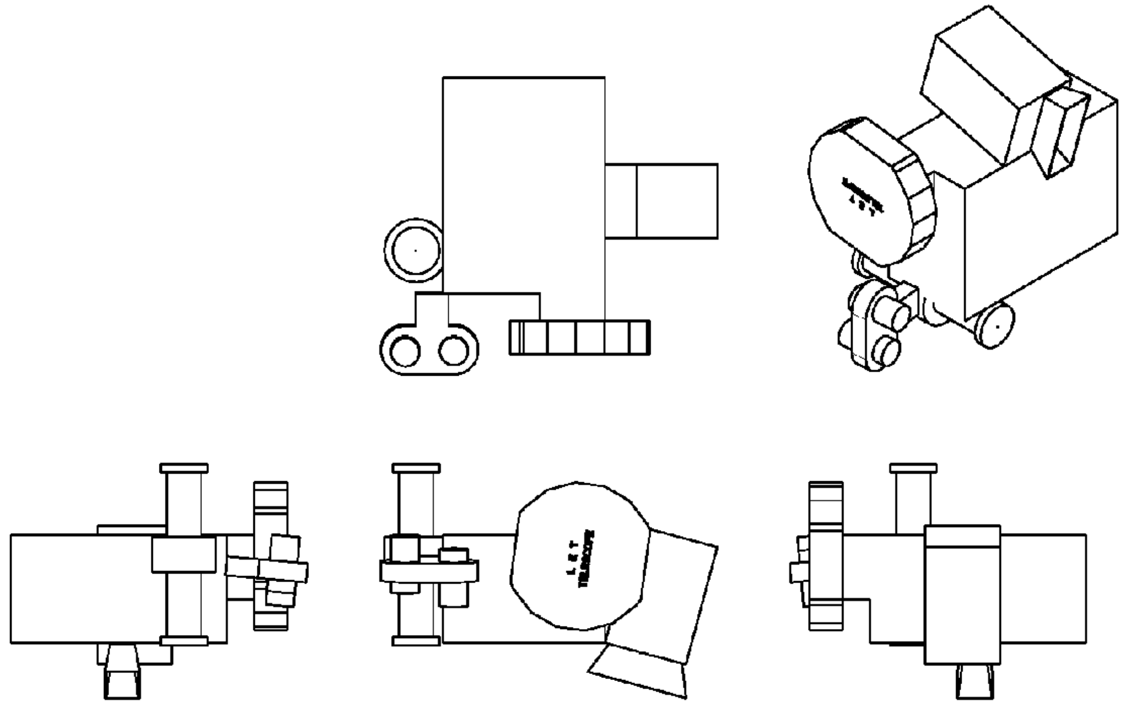
3.2.5. SWEA/STE/MAG Boom



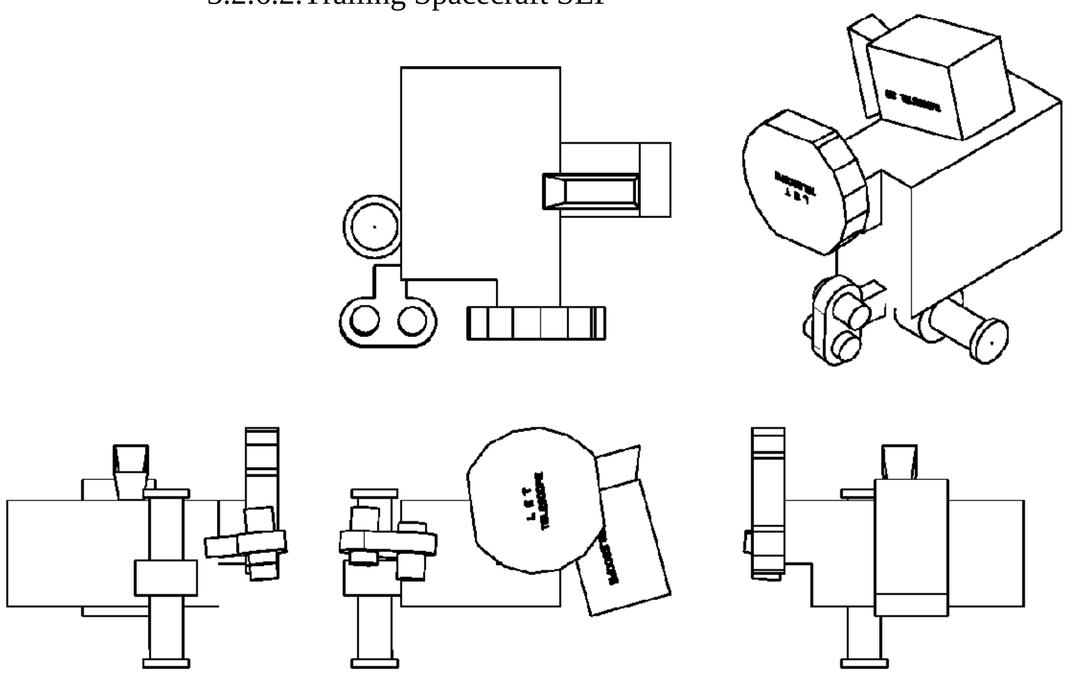
3.2.6. SEP

These figures need dimensions and FOV information added.

3.2.6.1. Leading Spacecraft SEP



3.2.6.2.Trailing Spacecraft SEP



3.2.6.3.SEPT-NS

TBD

3.3. FOV

3.3.1. SEP

See 3.2.6

3.3.2. SWEA

See 3.2.2

3.3.3. STE

See 3.2.3

3.4. Sun-avoidance

Some of the SIT, SEPT, the STE, and the SWEA apertures are sensitive to sunlight. In the normal orientation these apertures do not view the Sun, but in off-nominal orientations they might. This requires powering off SIT and possibly others of these instruments in off-nominal spacecraft orientations (TBR). There is also a possibility of damaging the SEPT sensors if exposed to continuous direct sunlight. The SEPT cover should be closed to prevent damage. See section 2.4.

3.5. Alignment placement & knowledge

The IDPU has no alignment requirements. The remaining boxes require +/-1 degree alignment, +/-0.5 degree knowledge, which should be obtainable by mounting tolerances.

3.6. Instrument Harnesses

IMPACT will have four harnesses from the IDPU to the following instruments:

SEP
SWEA/STE
MAG
PLASTIC

These harnesses carry digital and analog signals to/from the IDPU. They may also carry power and temperature sensor signals (see 2.5 and 1.7). There will also be a short pigtail on STE to SWEA, and a harness from SEP to SEPT-NS. (See also 3.7.1) .

3.7. SWEA/STE/MAG Boom Issues

Note that since the Astromast is now part of the IMPACT responsibilities, some of these requirements only indirectly affect the Spacecarft.

3.7.1. Harness

There are two harnesses to the SWEA/STE/MAG boom: the MAG harness and the SWEA/STE harness. The SWEA/STE harness carries spacecraft power and thermal (heater power & temperature sensors) to SWEA/STE, and serial digital data. The MAG harness carries analog signals plus thermal.

These harnesses need to be flexible for the deployment, be sufficiently shielded to meet EMC requirements, and have a conductive outer surface to meet ESC requirements. (This section of the harness is not included in the mass estimates in section 3.1)

3.7.2. Caging

It is expected that the SWEA/STE/MAG boom will be caged at both ends. The caging at the deployable boom is assumed to be part of the deployable boom mechanism. The caging at the SWEA end is assumed to be an IMPACT (Berkeley) responsibility. Mass for this is part of the Astromast allocation. There is some concern about ensuring that the caging mechanism does not get in the way of deployment or the SWEA/STE FOV.

3.7.3. Deployment

Deployment of the SWEA/STE/MAG boom will consist of releasing the caging mechanisms and then deploying the boom. A clear envelope must be provided to avoid having the fixed boom or instruments from impacting the spacecraft. The MAG sensor should be powered on during deployment to allow mapping of the spacecraft field. It is also desirable to have SWEA on during deployment, though that may be precluded by outgassing delays built into the SWEA high voltage turn-on sequence.

3.7.4. Shadow

SWEA aperature and all of STE must be in complete darkness for normal operations in order to keep STE cold and SWEA away from photoelectrons and scattered UV. Some kind of occulting disk will be needed; perhaps the end-plate of the deployable boom will be sufficient. The MAG sensor may also provide a shadow.

3.7.5. ESC

The deployable boom (and harnesses) must have a conductive exterior surface connected to spacecraft chassis ground to meet the SWEA ESC requirements. This can be achieved with a conductive paint, as was used on the Lunar Prospector Able mast.

3.7.6. Magnetics

The magnetic requirement is called out below. Since the MAG sensor is very close to the deployable boom, extra care must be taken. Magnetic materials must be avoided on the deployable boom. This includes the part of the caging mechanism that comes away with the boom. The deployable boom endplate should not be metallic as thermoelectric effects will cause magnetic fields; graphite-epoxy is OK.

4. Thermal

4.1. Temperature Limits

The thermal design shall be constrained so that qualification testing to predict +/-10C shall not exceed these limits. All limits are currently TBR

	Op.	Survival
SEP	-15C - +10C	-25C - +30C
SEPTNS	-15C - +10C	-25C - +30C
SWEA	-25C - +50C	-30C - +50C
STE	-50C - -30C	-50C - +40C
MAG	-20C - +45C	-20C - +45C
IDPU	-25C - +55C	-30C - +60C

4.2. Spacecraft interface

4.2.1. SWEA/STE/MAG Boom

SWEA/STE/MAG boom and its instruments shall be thermally isolated from the spacecraft by the deployable boom. It is not clear if the deployable boom endplate shall be thermally isolated or coupled to the rest of the SWEA/STE/MAG boom (TBD).

4.2.2. SEP/SEPT-NS

SEP and SEPT-NS shall be thermally isolated from the spacecraft

4.2.3. IDPU

The IDPU shall be thermally coupled to the spacecraft deck.

4.3. Survival Heaters

See section 2.3. The power level of these heaters is TBD; it needs to be adequate to maintain the survival temperatures indicated in 4.1 for all possible spacecraft attitudes.

4.4. Operational Heaters

See section 2.2.

4.5. Responsibilities

The instrument team shall take the lead in thermal design of the instrument boxes. This is expected to be primarily a passive design. The IDPU thermal design shall require more interactions with the spacecraft due to the conduction.

5. Contamination Control

IMPACT contains a number of contamination sensors such as Micro Channel Plates (MCP) and Solid State Detectors (SSD). These sensors are sensitive to water, hydrocarbons, and dust. To minimize the risk of contamination and simplify handling requirements these detectors will be sealed by flight or non-flight covers, and shall require near-continuous dry Nitrogen purge up to launch. Outside of this requirement, the instruments require class 100,000 or better when not bagged (includes in the launch vehicle shroud).

5.1. Purge

High quality dry nitrogen with low hydrocarbons is required. LN2 boil-off is preferred. Purge should be nearly continuous, but occasional outages up to an hour or two can be tolerated. The spacecraft purge manifold should be routed to SEP with a flow rate of TBD. SWEA and STE also require purge, but we understand that it will be difficult to route the spacecraft manifold to them because of the deployable boom. A separate GSE manifold will be acceptable, with purge discontinued at encapsulation of the spacecraft on the launch pad. The flow rate for SWEA/STE is 5 Liters/minute each, 10 Liters/minute total.

5.2. Covers

SIT, SWEA, SEPT and STE will have in-flight deployable (captured) covers to help maintain cleanliness through launch - see also section 2.4.1. All apertures will also have red-tag covers to exclude dust and contaminants.

5.3. Bagging

For vibration and other tests where non-flight covers are a problem, the instruments can be bagged instead. Also if the spacecraft is moved to an area not rated to Class 100,000 or better, the instruments should be bagged.

5.4. Humidity

The temperature/humidity of the instrument shall be maintained well above the dew point at all times.

5.5. Solvents

Avoid use of aromatic or oily hydrocarbons in the vicinity of SWEA, STE, or SEP. Ethyl alcohol is OK near SEP, Isopropyl near SWEA and STE.

6. Magnetics

The basic magnetics goal is that the dynamic field due to all spacecraft components be less than 0.05nT at the MAG sensor. The DC magnetic field can be subtracted out, so long as it is stable and is not so large that it forces the instrument into a less sensitive range. A goal should be to keep the DC field less than 1nT. The MAG team proposes to use the same magnetics cleanliness program used on ACE, MGS, WIND and POLAR to achieve and verify these levels at minimum cost. See also 3.7.6 on Boom magnetics.

6.1. Materials

Use of magnetic materials should be avoided. Where required, stray fields due to magnets and magnetic materials shall be computed at the sensor location to verify compliance with the goal. Failure of a subsystem to meet the goal should be discussed with the MAG team as soon as possible for possible mitigations.

6.2. Dynamics

Dynamic fields due to current loops in the bus can be a serious problem. All significant currents (>100mA) shall be returned in a twisted pair with the source (even inside boxes). Solar arrays shall be back-wired to minimize current loops. The SWEA/STE harness needs to be routed as far away from MAG as possible.

6.3. Operations

Use of magnetized tools in the vicinity of the MAG sensor shall be avoided. A tool monitoring station and de-perming equipment shall be provided.

7. ESC (SWEA)

SWEA measures the low energy electron distribution that can be easily disturbed by spacecraft differential charging. To avoid this the following steps must be taken.

7.1. Conductive Exposed Surfaces

The Mission Requirements Document calls for all exposed surfaces to be conductive and connected to spacecraft chassis ground. Exceptions (such as apertures) will have to be negotiated, and depend on the size of the non-conducting area and its proximity to the SWEA FOV, and if it is sunlit.

7.2. Solar Arrays

Both front and back surfaces of the solar array panels should be conducting. The method for grounding the front surface is in negotiation (TBR)

7.3. Boom

The deployable boom (astromast) will need to be conducting. An acceptable conducting surface preparation was used on a similar boom for Lunar Prospector.

8. Red/Green tags

8.1. Covers

SWEA, STE, SEPT-EW and NS, SIT, HET, and LET will have non-flight (red-tag) dust covers.

8.2. High Voltage Enable Plug

SWEA and SIT can be damaged by powering the high voltage on the ground. Note that no high voltage is exposed, so there is no personnel hazard. To mitigate the risk of damage, there will be a green-tag high voltage enable plug and/or a Red-tage high voltage disable plug on SWEA and SIT.

9. Spacecraft Stackup issues

9.1. Vibration

The upper of the two spacecraft is expected to get a higher vibration level. One of the two spacecraft has a longer SEP stub boom (to improve the SEP FOV). We would prefer that the spacecraft with the longer stub-boom be on the bottom so that it gets the lower vibration level, to minimize stiffness issues in the stub-boom. This is a relatively weak trade; we recognize that other concerns may drive this decision.

I&T

10. Spacecraft Simulators

IMPACT will require two spacecraft interface simulators for development and test of the instrument suite. These simulators are assumed to be adequate to verify the 1553 interface. However we strongly suggest one or more early interface tests of the prototype instruments with the prototype spacecraft systems to avoid problems.

10.1. Support for multi-instrument tests (IMPACT/SWAVES)

IMPACT and SWAVES communicate information via the 1553 interface (see 1.2 above). It is desired that we can use the spacecraft simulators to verify that interface, by attaching both units to a single simulator. We hope that the simulator will be capable of operating in this configuration, while allowing communication of commands and telemetry with both instruments, at least one at a time (TBR).

11. Command & Telemetry routing during I&T, Commissioning, and Diagnostics

    The IMPACT team shall provide a GSE capable of displaying telemetry from the instrument and formatting commands for the instrument. This GSE shall be designed to work with the Spacecraft-provided spacecraft simulator. It is hoped that the same interface will be provided to the spacecraft test and operations systems so that the same GSE can be used for Integration and test, during instrument commissioning and for diagnostic periods when near-real-time telemetry is available. During most of the mission this GSE will not be used except perhaps at the SCC for routine instrument health monitoring.

12. Purge, Covers, and bagging

    Contamination Control requirements during I&T up to launch re discussed in section 5 above. In addition, the hydrocarbon sensitivity requires that the thermal vacuum pumps NOT be oil-diffusion type.

13. Cleaning

    If it is determined that the instrument exterior needs to be cleaned, cleaning shall be performed by a member of the instrument team or their designee. See also section 5.

14. Ionizing Radiation Sources for test

    In order to stimulate the various detectors, low level radiation sources will be required for any comprehensive test (including Thermal Vacuum). Internal stimulation can be used for limited tests to verify electronics but not detectors. Possible sources include:

    Ni63, Am241, Co60, Th238

15. High Voltage Issues

    SWEA and SIT contain a number of high voltage supplies (up to 3500V) which cannot be run in air (damage may occur to the detectors). None of this high voltage is exposed, so there is no risk to personnel. Green-tag enable connectors must be installed to enable the high voltage; they will not be installed for most of the I&T operations. High voltage may be used during thermal vacuum tests if the pressure at the detectors is below 10E-5 Torr.

16. SEP Test Access Connectors

    SEP will have a test access connector(s) that we would like to connect to during instrument tests when possible.

17. One-time Opening Covers

SWEA and SIT have 1-time opening covers. Since these covers are part of the contamination control of these instruments, and since reclosing these covers may be difficult, tests of these covers shall be limited to perhaps only Thermal Vacuum. Simulators can be provided for testing the spacecraft.

17.1. Reclosable Covers

STE and SEPT will have reclosable covers. These covers can be tested at any time provided the instruments have their dust covers on, or the instruments are in a class 100,000 or better clean area, or are bagged.

18. Post Environmental Tests

SWEA and SIT detectors cannot be tested in air. SIT can be tested adequately in Thermal Vacuum, but SWEA cannot. All systems should be comprehensively tested after environmental tests to verify no damage has occurred. So long as Thermal Vacuum test is the last environmental test, SIT should be OK. SWEA will need to be removed from the spacecraft and returned to Berkeley for a complete test in the calibration facility after Spacecraft environmental tests.