STEREO IMPACT

System Requirements Review Presentation

David Curtis

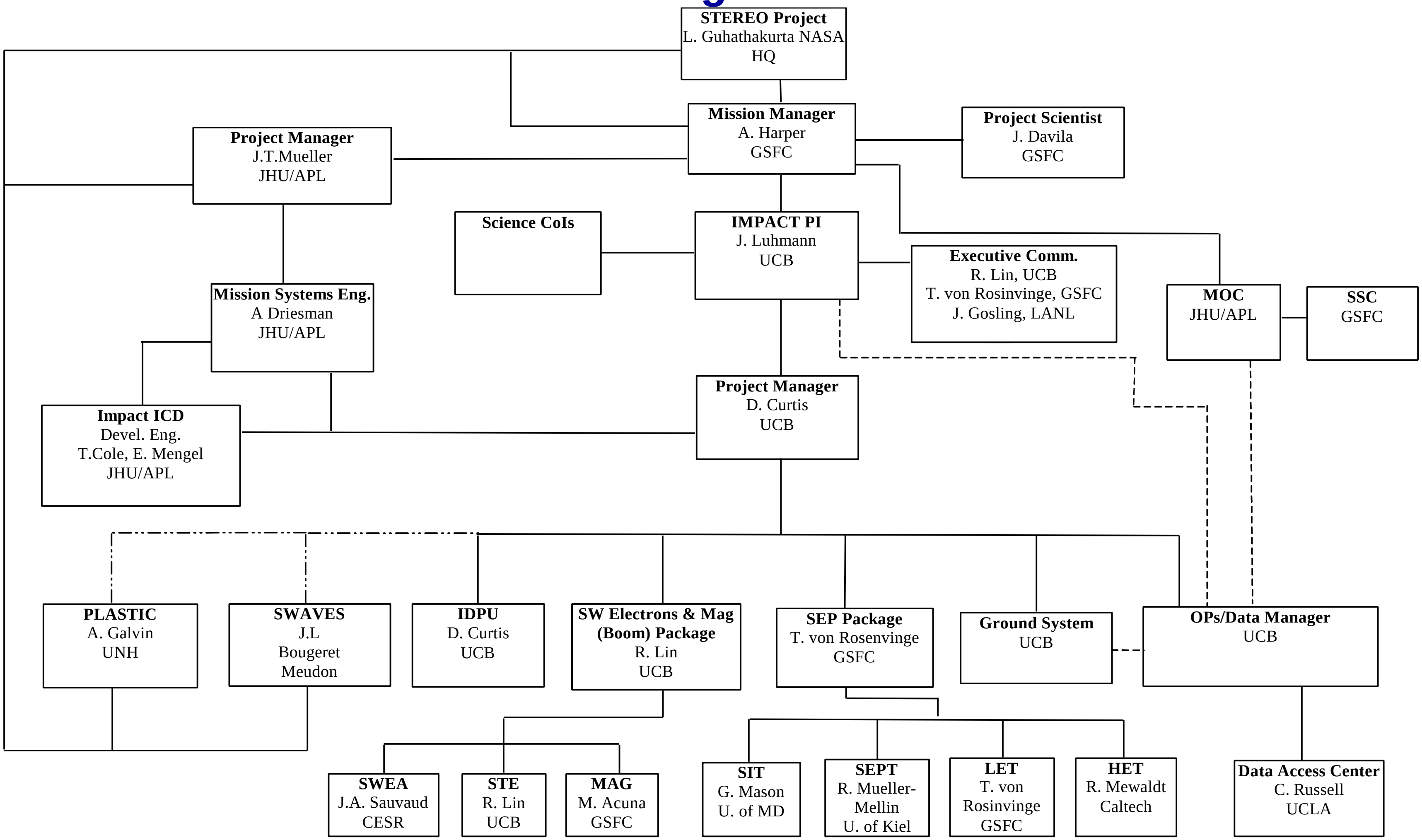
Presentation Outline

- Instrument Overview
  - Science Requirements
  - Team Organization
  - Instrument Block Diagram
- Instrument Requirements
  - Spacecraft Interface Requirements
  - Instrument I&T Plans
  - Spacecraft I&T Requirements
  - Launch Site Requirements
  - Mission Requirements
  - Open Interface Issues and Trades
- Programmatics
  - Risk Assessment
  - Requirements & Resource Tracking Plans
  - Configuration Control Plan
- Supporting Material

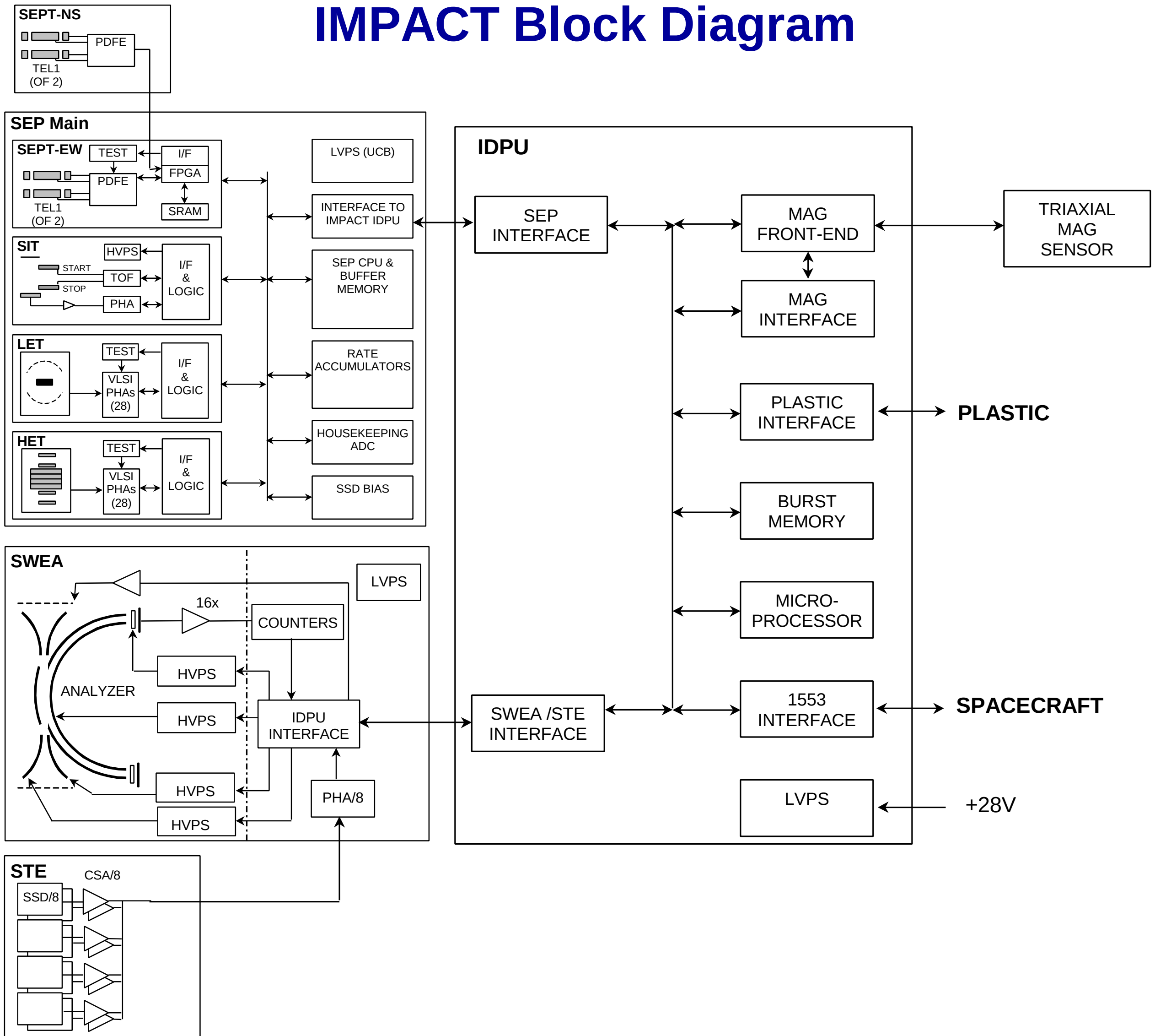
IMPACT Science Summary

Exper	Instr	Measurement	Energy or Mag. Field Range	Time Res.	Instrument Provider
SW	STE	Electron Flux and anisotropy	2-100 keV	1 min	UCB (Lin)
	SWEA	3D electron distrib., core & halo density, temp. & anisotropy	~0-3 keV	1 min	CESR (Sauvaud)
MAG	MAG	Vector field	±500 nT, ±65536 nT	¼ s	GSFC (Acuna)
SEP	SIT	He to Fe ions	0.03-2 MeV/nuc	30 s	U. of MD (Mason) + MPAE (Livi)
	SIT	^{3}He	0.15-0.25 MeV/nuc	30 s	
	SEPT	Diff. Electron flux	20-400 keV	1 min	U. of Kiel (Mueller-Mellin) + ESTEC (Sanderson)
	SEPT	Diff. Proton flux	20-7000 keV	1 min	
	SEPT	Anisotropies of e,p	As above	15 min	
	LET	Ion mass 2-28 flux & anisotropy	1.5-40 MeV/nuc	1-15 min	GSFC (von Rosenvinge) + Caltech (Mewaldt) + JPL (Wiedenbeck)
	LET	^{3}He ions flux & anisotropy	1.5-1.6 MeV/nuc	15 min	
	LET	H ions flux & anisotropy	1.5-3.5 MeV	1-15 min	
	HET	Electrons flux & anisotropy	1-8 MeV	1-15 min	Caltech (Mewaldt) + GSFC (von Rosenvinge) + JPL (Wiedenbeck)
	HET	H	13-100 MeV	1-15 min	
	HET	He	13-100 MeV	1-15 min	
	HET	^{3}He	15-60 MeV/nuc	15 min	

IMPACT Team Organization Chart



IMPACT Block Diagram



C&DH Interface

- **All Command, Telemetry, Status, and Timing exchanged between IMPACT/PLASTIC IDPU and Spacecraft C&DH via 1553 bus**
  - ***Implementation of 1553 Interface as called out in draft ICD is adequate for IMPACT needs***
  - **IMPACT will provide CCSDS-formatted packets for science and housekeeping telemetry (510bps) as well as Beacon mode (8bps) data via the 1553 interface**
  - **Packets will be time-tagged (packet collect time) using UTC time code provided over the 1553 interface**
  - **Spacecraft status provided over the 1553 bus will be used to control the IMPACT instrument (e.g. some detectors off for thruster firing events)**
- **A small quantity (<1kbyte/day) of time-tagged commands will be required to coordinate activities**
  - **The IDPU can perform this function if the spacecraft cannot**
- **Instrument "Burst" mode data will be managed by the IDPU within the instrument telemetry allocation with no impact on the spacecraft**

Power Interface

- **IMPACT converts unregulated 28V provided by the spacecraft per the ICD**
- **IMPACT has three power inputs with separate converters for modularity and reliability:**
  - **IDPU/MAG**
  - **SEP**
  - **SWEA/STE**
- **Separate power inputs from the spacecraft for each converter are desirable but not required**
- **We currently expect to require no Operational Heaters (TBR)**
- **We will require Survival Heaters when the instrument is powered off**
  - **Survival heat is also needed in some off-nominal attitudes, which may require powering off the instrument to enable the Survival Heaters if they are exclusive.**

PLASTIC Interface

- **The IMPACT IDPU also services the PLASTIC instrument**
  - **The IDPU provides a single-point interface for both IMPACT and PLASTIC to the spacecraft C&DH system.**
  - **The IDPU will process, format, and pass on to the C&DH system PLASTIC telemetry**
  - **The IDPU will control the PLASTIC instrument operation**
  - **A high-speed bidirectional serial digital interface between IDPU and PLASTIC carries status, data, and control information.**
- **Advantages of a shared IMPACT/PLASTIC IDPU**
  - **Real-time data from PLASTIC is used to control SWEA spacecraft charging bias**
  - **Coordinated collection of high speed "Burst" event data**
  - **Resource savings (Mass, power, $)**
- **PLASTIC IDPU software developed at UCB to PLASTIC requirements**
  - **UCB wrote flight software for similar UNH instruments on CLUSTER and FAST**

SWAVES Interface

- **Coordination of high speed "Burst" event data between SWAVES and IMPACT/PLASTIC scientifically highly desirable**
- **Bandwidth required: A few words at a few Hertz**
- **This has been accommodated via the spacecraft 1553 bus**
  - **avoids a physical interface between SWAVES and IMPACT**

FOV Issues, SWEA

- **SWEA has a very large FOV (nearly 4pi) which is accommodated by location at the end of a long boom.**
- **Small objects in SWEA FOV are acceptable, such as SWAVES antennas**
- **Greater sensitivity to ElectroStatic Cleanliness issues for objects in/near the SWEA FOV**
- **SWEA aperture should be out of sunlight**
  - **reduces photoelectron issues**
  - **reduces detector sunlight sensitivity concerns**
- ***Current spacecraft configuration is acceptable***

FOV Issues, STE

- **STE has a moderately large FOV (two 80 by 80 degree oppositely-directed windows)**
- **FOV should be centered on Parker spiral for optimal viewing**
- **STE FOV can have small blockages, but there is significant concern about scattered sunlight**
  - **SWAVES Antennas are a concern**
- **STE should be out of sunlight**
  - **Thermal: want to be cold**
  - **Avoid scattered light issues**
- ***Current spacecraft configuration is acceptable***
  - **Minor adjustments to STE FOV and SWAVES antenna configuration have been made to avoid scattered light issues**
  - **SWEA/STE/MAG Boom will have two mounting locations for STE to accommodate different orientations on the two spacecraft**

FOV Issues, SEP

- **Concessions to Clear IMPACT/SEP View Angles**
  - Separated SEPT-N-S from the rest of SEP
  - Reduced SEPT 70 degree FOV to 60 degrees
  - Relaxed pointing direction requirements by 9 degrees in ecliptic plane and 5 degrees out of ecliptic plane
  - Accepted mounting positions well off the spacecraft body
  - SEP boxes are different for Trailing and Leading Spacecraft
  - Detector FOVs are reversed front/back between trailing/leading spacecraft
- **CONCERNS**
  - Some impingements to FOV remain, need to be worked
  - Potential growth of Solar Array into FOV
  - Cantilevered design requires stronger, larger enclosure plus mounting brackets - undetermined mass impact
  - Off-body location has increased vibration and thermal risks

SEP FIELDS OF VIEW: TRAILING SPACECRAFT

Telescope	Nominal			Current			Impingements	
	Phi	Theta	FOV	Phi	Theta	FOV	**Forward (N)**	**Backward (S)**
SEPT- N/S	-	90	60, 70	-	90	60, ***60***	***Corner of Spacecraft Lower Deck***	***Corner of Spacecraft Lower Deck***
SEPT-ECLIPTIC	45	0	60, 70	***43***	***5***	60, ***60***	None	None
SIT	60	0	44 x 17	60	0	44 x 17	None	N/A
LET	45	0	133 x 30	***52.5***	0	133 x 30	***Plastic***	***Spacecraft Body***
HET	45	0	47.5	45	0	47.5	None	None

Note: Phi = angle between spacecraft-sun line and the field of view central axis projected onto the ecliptic plane

Theta = angle between field of view central axis and ecliptic plane

Impingements with SWAVES antennas have been ignored

SEP FIELDS OF VIEW: LEADING SPACECRAFT

Telescope	Nominal			Current			Impingements	
	Phi	Theta	FOV	Phi	Theta	FOV	Forward (N)	Backward (S)
SEPT- N/S	-	90	60, 70	-	90	60, ***60***	***Corner of Spacecraft Lower Deck***	***Corner of Spacecraft Lower Deck***
SEPT-ECLIPTIC	45	0	60, 70	45	***5***	60, ***60***	None	None
SIT	60	0	44 x 17	60	0	44 x 17	None	N/A
LET	45	0	133 x 30	***54***	0	133 x 30	None	***Spacecraft Body***
HET	45	0	47.5	45	0	47.5	None	None

Note: Phi = angle between spacecraft-sun line and the field of view central axis projected onto the ecliptic plane
Theta = angle between field of view central axis and ecliptic plane
Impingements with SWAVES antennas have been ignored

Thermal Interface

- Thermal Requirements:
  - SWEA -25 - +50C Operational -30 - +50C Survival
  - STE -50 - -30C Operational -50 - +40C Survival
  - MAG -20 - +45C Operational -20 - +45C Survival
  - SEP -15 - +10C Operational -25 - +30C Survival
  - IDPU -25 - +55C Operational -30 - +60C Survival
- IDPU shall be thermally coupled to the spacecraft. The rest are thermally isolated.
- Limited SEP upper survival temperature due to SSD sensitivity
- SEP and STE biased cold operationally to minimize SSD noise
- IDPU thermal requirements match spacecraft deck
- SWEA, STE, MAG are remote from Spacecraft, and so thermally decoupled.

Alignment

- IDPU has no alignment requirements
- IMPACT Instruments have modest alignment requirements:
  - ±1º alignment
  - ±0.5º knowledge
  - Should be obtainable by mounting tolerances
  - SWEA/STE/MAG boom deployed orientation repeatability may be an issue; has not been on similar booms on previous spacecraft.

Contamination Control

- **SEP, SWEA, and STE include Solid State Detectors (SSD) and Microchannel Plates (MCP)**
  - **SSD are sensitive to condensables**
  - **MCP are very sensitive to some hydrocarbons, water, and dust**
- **Design will use low-outgassing materials (1%TML, 0.1%CVCM)**
- **Once integrated, contamination control requirements consists of purge, aperture covers, and good housekeeping cleanliness levels**
  - **SEP and SWEA require purge with high quality LN2 (boil-off is adequate). Occasional outages are acceptable.**
  - **SWEA and SIT have 1-time opening covers to exclude contamination to MCPs through launch**
  - **All apertures have red-tag covers to protect detectors through testing**
  - **Elevated cleanliness levels will be imposed during tests that require covers to be removed (level depends on duration and which covers)**
    - **Some concern about Thermal Vacuum chamber cleanliness (TBR)**

Magnetics

- Magnetic Goals, as measured at the MAG sensor:
  - ±0.05nT Dynamic
  - ±1nT Static
- Use of magnetic materials needs to be avoided/controlled
- Current loops need to be minimized
- Items close to MAG sensor are of particular concern (since field falls off at least as R^3).
  - SWEA, STE, and IMPACT-provided rigid boom
  - APL-provided deployable IMPACT Astromast.
- MAG team will work closely with APL to help meet these requirements at minimum cost
  - MAG team will screen selected spacecraft components
  - MAG Team will magnetically map spacecraft during I&T
- Mission Constraints: Spacecraft rolls and having MAG on during boom deployment will aid in determining spacecraft DC magnetic fields so they can be subtracted

Electro-Static Cleanliness (ESC)

- **SWEA measures low energy electrons (down to about 1eV) whose trajectories are easily distorted by spacecraft charging**
  - **Desire is to avoid deflecting 1eV electrons more than 5°**
- **All exterior surfaces shall be conductive to at least 10^8 Ohms/Square (derived from a 1V charging requirement)**
  - **Exceptions, such as apertures, to be negotiated on a case-by-case basis, based on area, sunlight, and proximity to the SWEA FOV**
    - **£0.2% total non-conductive surface area goal**
- **Possible Issues:**
  - **Solar Arrays: Study in progress to determine what level of ESC close-out of solar array cover glass is required**
  - **Deployable boom: will probably require conductive paint, such as what was used for Lunar Prospector Able mast**
  - **HGA: have had problems on previous missions getting the HGA exterior surface (paint) conducting**
  - **Thermal control paints**
  - **Apertures**

Safety

- **Safety issues for IMPACT consist of high voltage and radiation sources**
- **High Voltage Risk Mitigations:**
  - **No exposed high voltage**
  - **Supplies are current-limited by output series resistors**
  - **Green-tag high voltage enable and/or Red tag high voltage disable plugs will be used to avoid inadvertent application of high voltage that could damage MCP detectors in SWEA and SIT**
  - **Procedural constraints will be developed in I&T procedures to avoid inadvertent application of high voltage that could damage detectors**
- **Radiation Source Risk Mitigations:**
  - **Qualified Instrument Team personnel only will handle sources, using standard radiation safety procedures**
  - **Opportunities to use sources at the spacecraft level need to be negotiated**

Instrument-Level I&T Plan

- Engineering Models of selected subsystems will be integrated and tested early to verify interfaces
- Flight Instruments will first be functionally tested and calibrated at their home institution prior to delivery for integration to UCB
- The instrument suite will be integrated and tested at UCB prior to delivery to the spacecraft integration
- I&T testing at UCB includes interface and system level functional tests, compatibility tests, and environmental qualifications
  - SEP will have environmental tests prior to delivery to UCB
- Pre-delivery bake-out and exterior cleaning as required to meet spacecraft-level contamination control plan

Instrument Verification Plan

- **System Functional Test proves end-to-end functionality**
  - **Constrained by inability to test SWEA and SIT detectors in atmosphere**
  - **This test is also performed in thermal vacuum**
  - **A limited version of this test is performed between environments**
- **Environmental Tests:**
  - **EMC, as required**
  - **Mass Properties**
  - **Acoustics if indicated by analysis of design**
  - **Random Vibration**
  - **Thermal Vacuum**
- **Minimum 100 hours trouble-free operation prior to spacecraft integration**
  - **expect to have considerably more**

GSE

- Electrical GSE includes:
  - Spacecraft-provided spacecraft interface simulators
  - UCB provided Telemetry/Command GSE (also used at spacecraft-level I&T and mission ops)
  - UCB-provided IDPU interface simulators for SEP, SWEA/STE, and PLASTIC
  - UNH-provided PLASTIC ETU/simulator for PLASTIC software development/test (TBR)
  - Bench equipment for low-level detector tests and calibrations
- Electrical GSE are typically PC-based systems with commercial or custom interface cards to provide interface signal simulation
- Radiation Sources will be used to stimulate detectors for comprehensive functional tests
- Internal pulsers provide electrical stimulation for bench tests when radiation sources are not available
- MAG team will provide magnetic screening GSE

Special Spacecraft I&T Requirements

- Low level radiation sources are required for comprehensive functional tests (SEP and STE)
- SWEA and SIT detectors (MCP) cannot be tested except in vacuum.
  - SIT can be tested adequately in thermal vacuum using a low level radiation source
  - SWEA cannot be adequately tested in thermal vacuum
    - Request SWEA be returned to Berkeley for post-environmental functional test (about 2 weeks)
- SWEA and SIT HV Arming plugs shall only be installed for Thermal Vacuum, and as late as possible before Launch
- Near real-time command and telemetry are required to perform instrument tests. An elevated telemetry rate is desirable to make the tests run at a reasonable speed

Instrument Handling

- Any cleaning procedure used on or near the IMPACT instrument should be cleared with the IMPACT Team first
- Avoid use of aromatic or oily hydrocarbons near SWEA, STE, and SEP. Ethyl for SEP and Isopropyl for the other instruments is OK.
- Avoid magnetic materials or tools near MAG. Screen tools before using them near MAG sensor
- Keep dust covers on apertures as much as possible. Contact IMPACT Team when removal is required.

Launch Site Requirements

- **Pre-encapsulation access to verify instrument configuration**
  - **Remove red-tag dust covers**
  - **Install SWEA HV enable plug, remove SIT HV disable plug**
  - **Remove SWEA purge line**
- **Since dust covers are off and SWEA is not purged post-encapsulation, the fairing must be clean (class 100,000 or better)**
  - **Historically the night before the launch they light up the bird using diesel powered arc lights. They always put the diesel generators right in front of the fairing air intake. Maybe if we ask early enough they can put the diesel generators downwind of the air intake.**
- **Great care must be taken if the instrument is powered after the HV enable plugs are installed. Inadvertent powering of instrument HV can destroy the instrument.**

On-Orbit Instrument Commissioning Phase

- Would like IMPACT powered on and the IMPACT boom deployed as soon as possible after launch
- At least IDPU/MAG should be powered on prior to boom deployment. This will provide valuable data for modeling of the spacecraft field, and can also provide a deployment diagnostic
- Instrument covers must remain closed at least one hour after orbit injection to allow time for the spacecraft to outgas
- Instrument covers must be opened at least one hour prior to high voltage being applied to allow time for detector to outgas
- Near real-time telemetry and commanding is required for instrument commissioning (at least while high voltage is being ramped up). An enhanced instrument telemetry rate in this interval is desirable
- Avoid SEP or STE commissioning in radiation belts
- Possible damage to detectors by magnetospheric energetic particle environment or sunlight may constrain early operations

Rolls

- **Slow spacecraft rolls about the sun-line are required to calibrate the MAG DC offsets during the commissioning phase**
- **Rolls are also desirable for the other IMPACT instruments, to separate spatial effects from spacecraft effects in the measured particle distributions**
- **Rolls should occur in a low field region such as the solar wind**
- **Several rolls are desirable in case the ambient magnetic field is active during the measurement**
- **Rolls later in the mission, every six months, will measure the drift in the spacecraft DC fields and MAG sensor offsets**

Mission Requirements

- Instrument operation may be constrained during off-nominal spacecraft orientation
  - Some detectors must be turned off if their FOV is in sunlight
  - Some detectors may need to be in survival mode in off-nominal orientations in order to control temperature
  - Reclosable covers may be required to avoid sunlight in some apertures (TBR)
- The IDPU is designed to require little day-to-day commanding; only the occasional mode change or parameter fine-tuning
- The system does require the ability to load sizeable memories, but very rarely

Resource Issues

- No Operation Heaters budgeted; this needs to be revisited after a thermal design is completed
- Mass does not include SEP bracketry; pending analysis
- Mass does not include Thermal Blankets
- Mass includes in-flight one-time opening aperture covers for SWEA and SIT. SEPT, HET, LET and STE may also require covers (TBR)
- Mass does not include boom caging mechanism; design pending discussions with APL
- Telemetry allocations are very thin
  - Logistical concern with the slow rate of data updating
  - Large data compression ratios used (mostly averaging)
  - We can meet the science requirements within the current allocation
- Resource estimates assume aggressive optimization. Less optimization (more mass) would decrease schedule/cost risk.

Other Open Spacecraft Interface Issues

- **IMPACT boom interface, caging mechanism, and deployment issues need more work**
- **SEP Mechanical Interface pending bracket design**
- **Thruster locations, possible plume contamination issues**
- **SEP FOV; mostly accommodated, pending final iteration**
- **ElectroStatic cleanliness surface conductivity exceptions need to be worked**

Trade Studies in progress

- Researching parts issues and their impact on resources
- Thermal design needed so we can determine if operational heaters or radiators are required
- Studying impacts of design changes made in SEP to clear its FOV
- Iterating design details to better determine resource requirements
- Studying need for in-flight covers for SEPT, HET, LET, and STE
  - Sunlight in aperture avoidance in off-nominal attitudes (overheating)
  - Contamination Control
  - Radiation damage in magnetosphere
- Studying practicality of performing adequate functional testing of SWEA in spacecraft thermal vacuum
- Studying impact of SWAVES antenna in SEPT FOV (scattered light)

Risk Assessment

- **Risk areas monitored regularly by PI and Project Manager**
- **Schedule and criteria for implementing contingency plans to be developed**

Risk Area	Contingency Plan	Impact
International Support	Transfer responsibility to US team member	Increased US Cost or descope
STE noise level	Increase threshold	Lose lowest energy, SWEA overlap
SIT hybrids	Non-hybrid solution	Mass, Power
SIT TOF	Existing design	Mass, Power
LET/HET VLSI	Existing design	Mass, Power
LET thin detectors	Spare Wind/LEMT detectors	Reduced reliability, sensitivity
Mass, Power, Cost	Descope STE	Reduced angular resolution
	Descope SWEA Deflectors	Reduced angular coverage
	Remove Burst Memory	Loss of high time resolution data
	Eliminate SEPT-NS	Reduced performance
	Reduce # of HET/LET detectors	Reduced performance
	Eliminate SIT	Reduced performance

Requirements and Resource Tracking Plans

- Instrument Science Requirements are documented in the proposal (to be updated in the Phase A Report)
- Interface requirements and resource allocations are called out in the spacecraft to Instrument Interface Control Document, controlled by APL
- Mission and other requirements controlled by Project documents, with IMPACT input
- Resources requirements shall be regularly monitored by the Project Manager as the instrument matures
- Resource margins shall be maintained at a level appropriate to the maturity of the design.
  - The IMPACT PI and Project Manager shall perform resource trades (mass/power/schedule/money/science goals) within the team to maintain adequate margins
  - Inability to maintain adequate margins shall be referred to the STEREO Project Manager as soon as identified

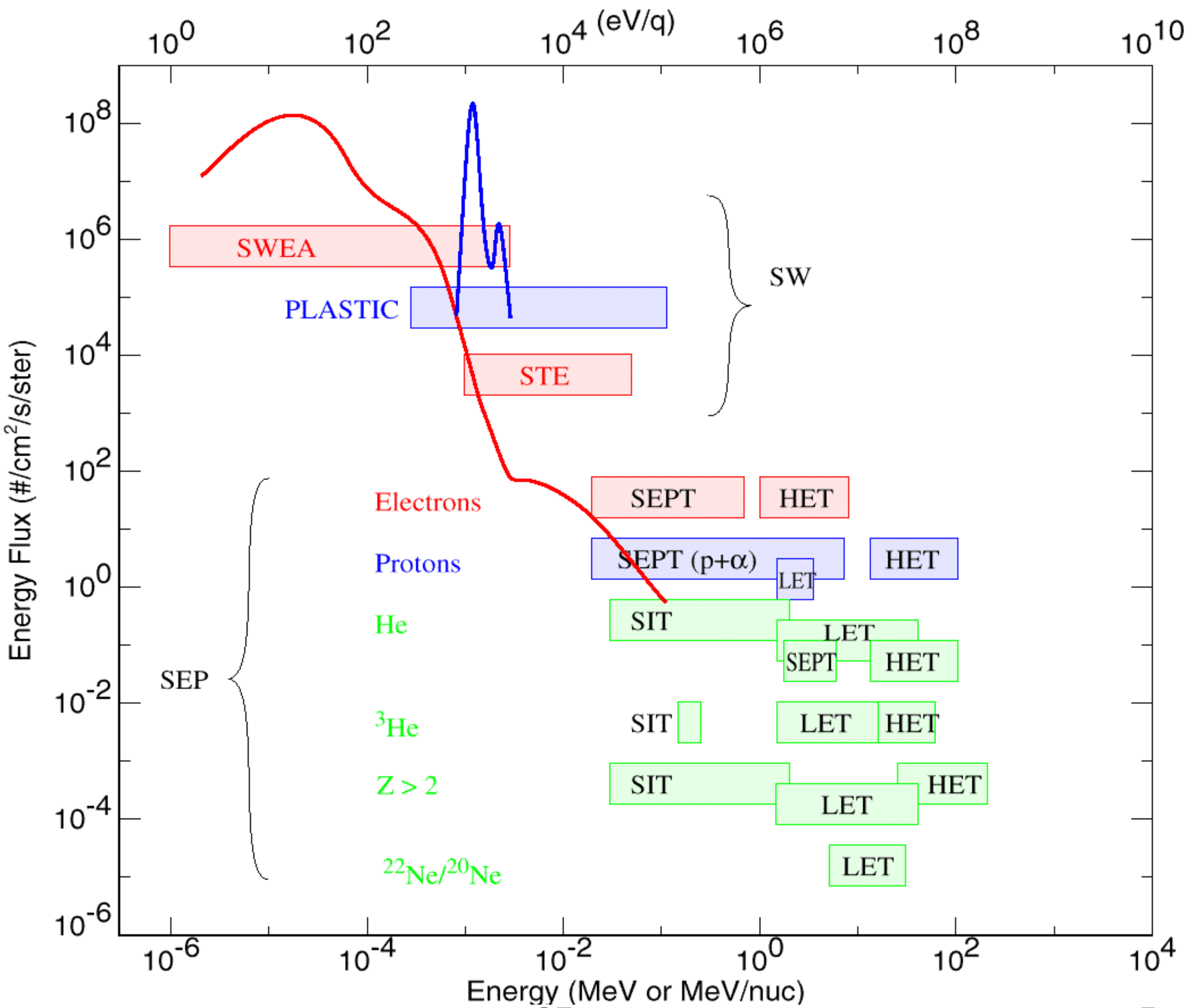
Configuration Control

- **Top-level documents, such as Specifications, Interface Control Documents, and Manuals, shall be maintained on the Berkeley web-page**
  - **ICDs shall be used to control all flight hardware interfaces between institutions in the IMPACT team**
  - **Notification of revisions and concurrence of top-level documentation shall be by e-mail**
- **Lower level design documentation shall be maintained by the cognizant engineers**
- **Fabrication records, such as as-built drawings, manufacturing travelers, certifications, test and calibration reports shall be maintained at the fabrication institution**

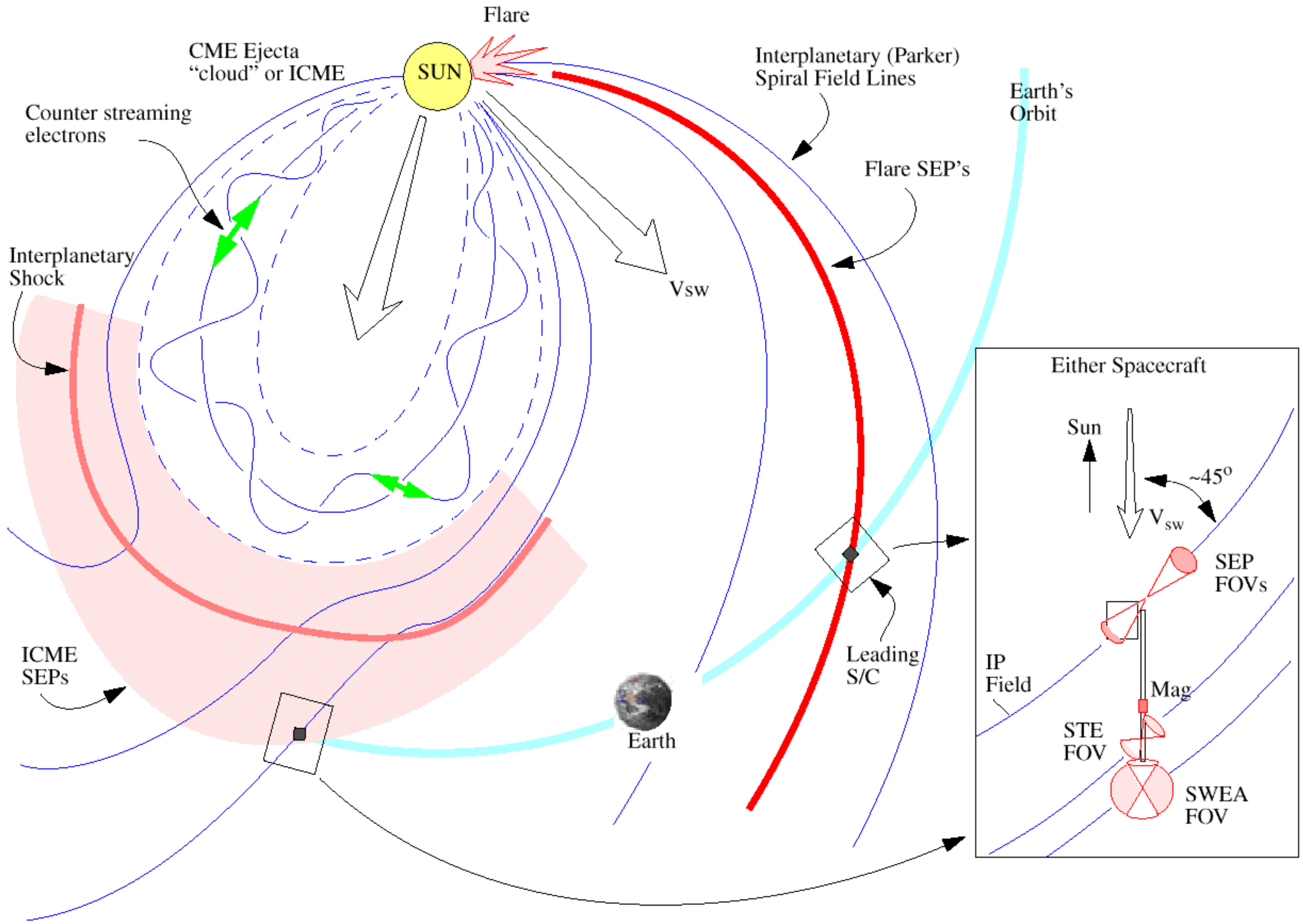
STEREO IMPACT

System Requirements Review
Supporting Material

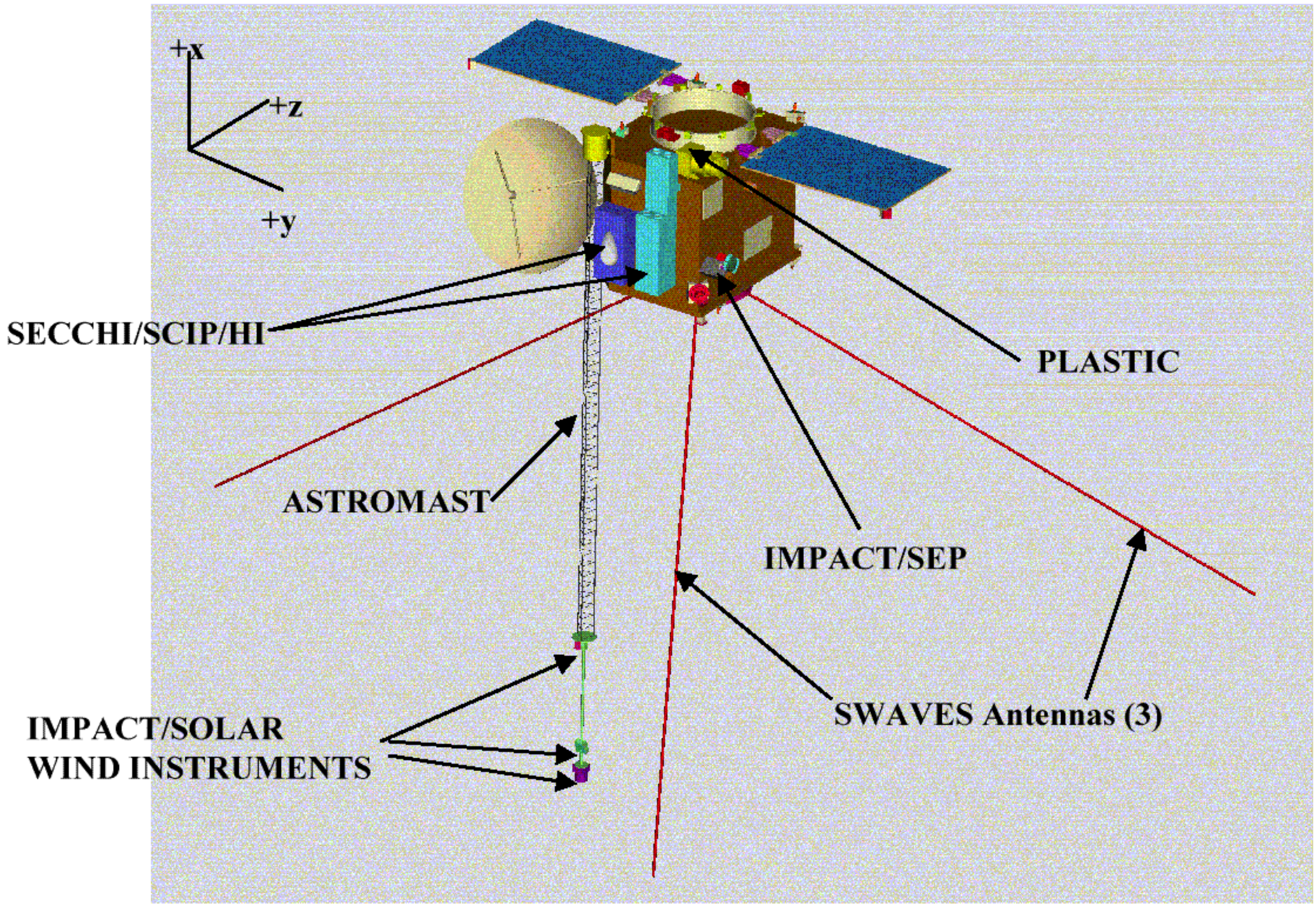
IMPACT / PLASTIC Energy Coverage

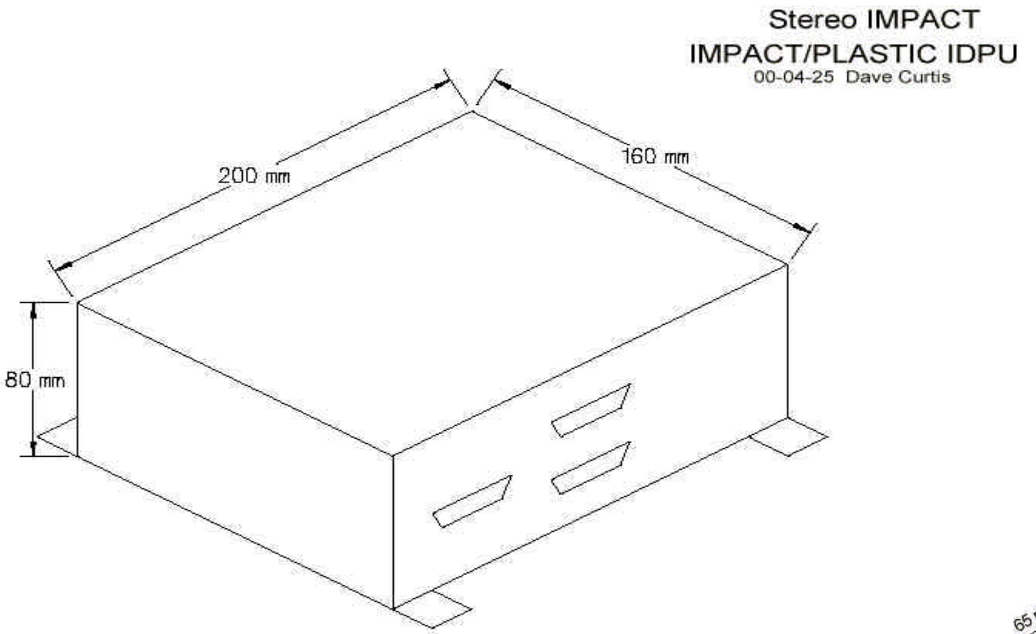


IMPACT Science FOV Motivation

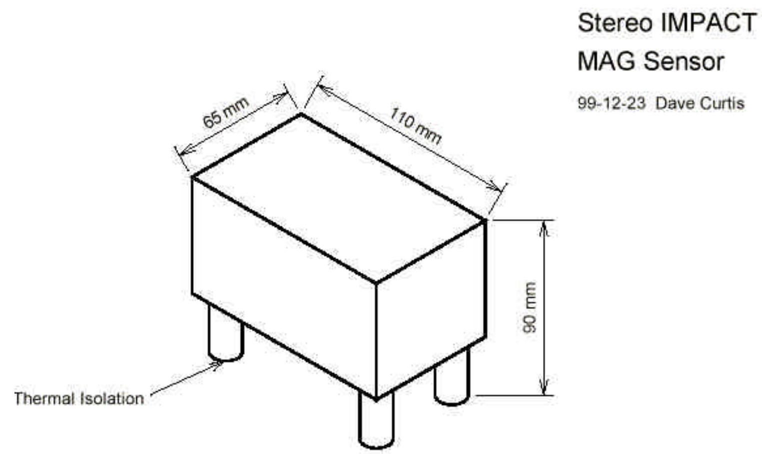


STEREO Trailing Spacecraft, IMPACT Instrument Locations

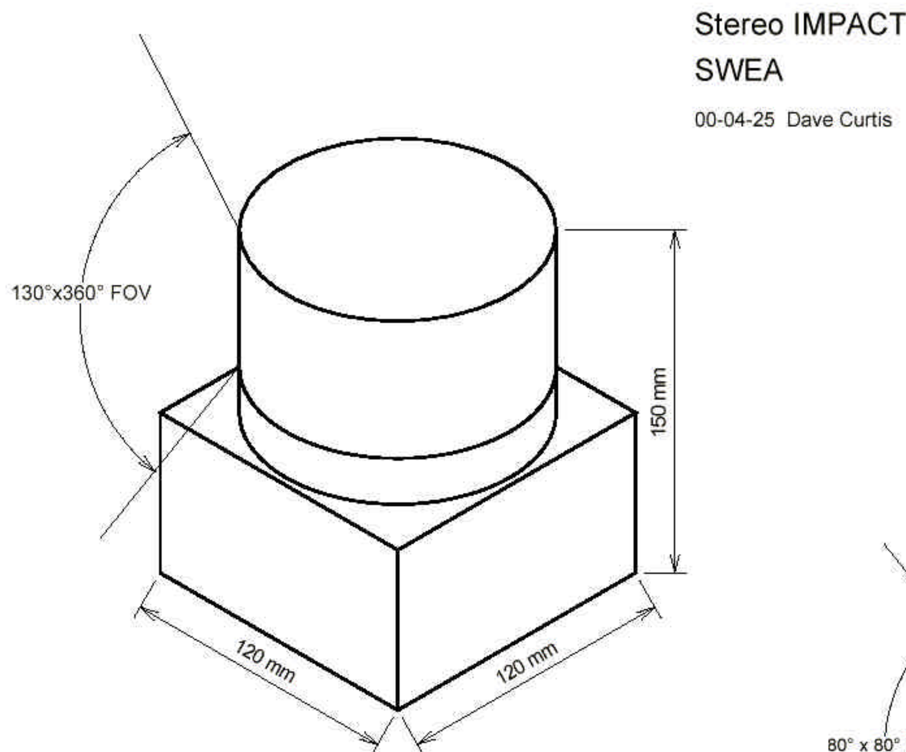


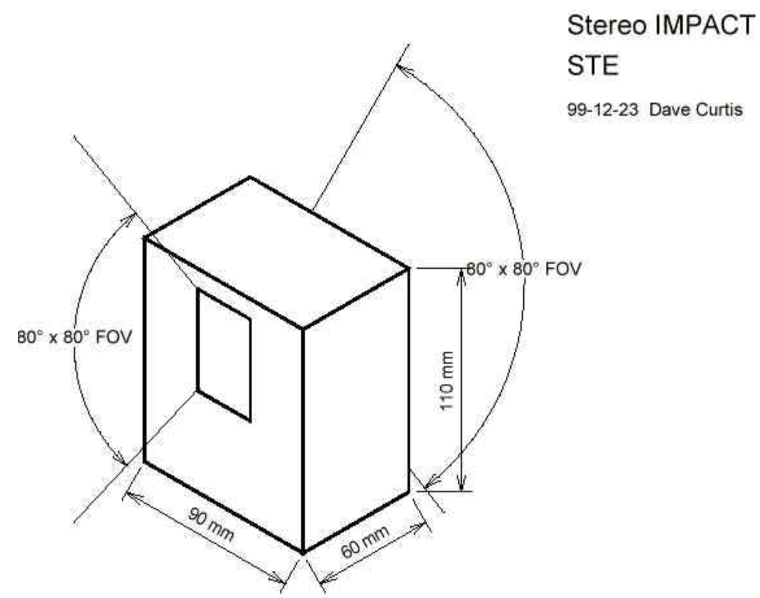


Stereo IMPACT
IMPACT/PLASTIC IDPU
00-04-25 Dave Curtis
200 mm
160 mm
80 mm

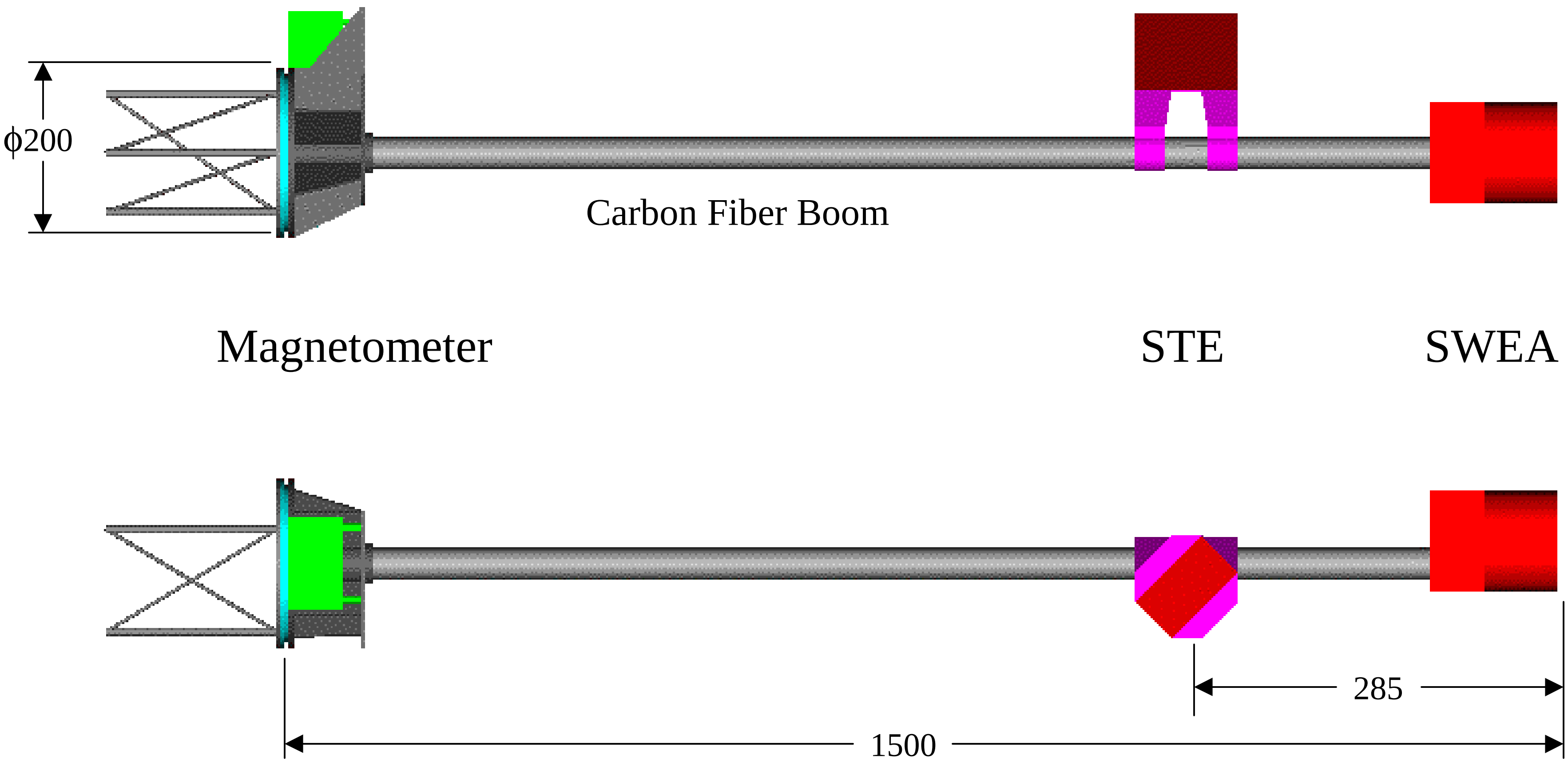


Stereo IMPACT
MAG Sensor
99-12-23 Dave Curtis
65 mm
110 mm
90 mm
Thermal Isolation

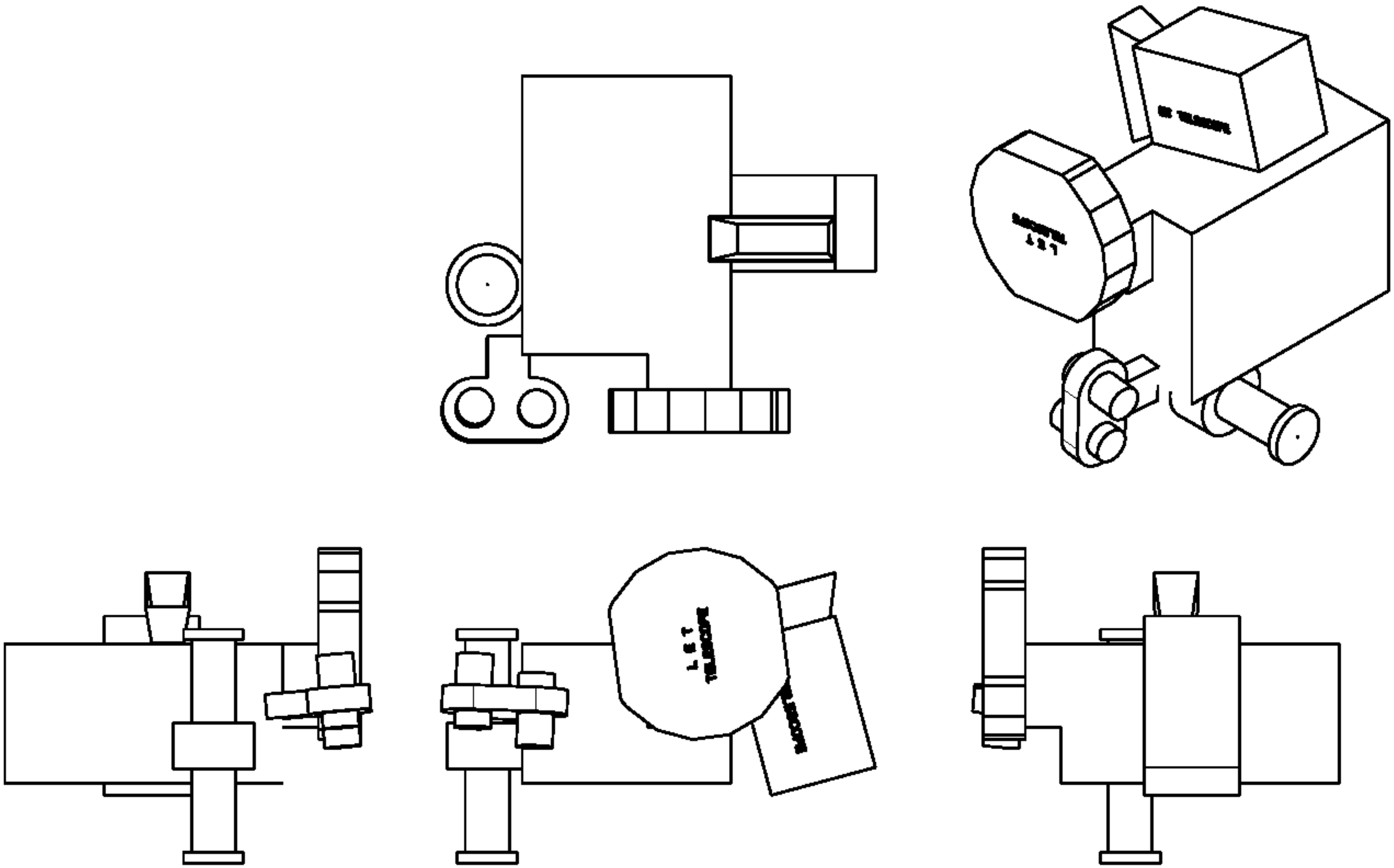

Stereo IMPACT
SWEA
00-04-25 Dave Curtis
130°x360° FOV
150 mm
120 mm
120 mm


Stereo IMPACT
STE
99-12-23 Dave Curtis
80° x 80° FOV
80° x 80° FOV
110 mm
90 mm
60 mm

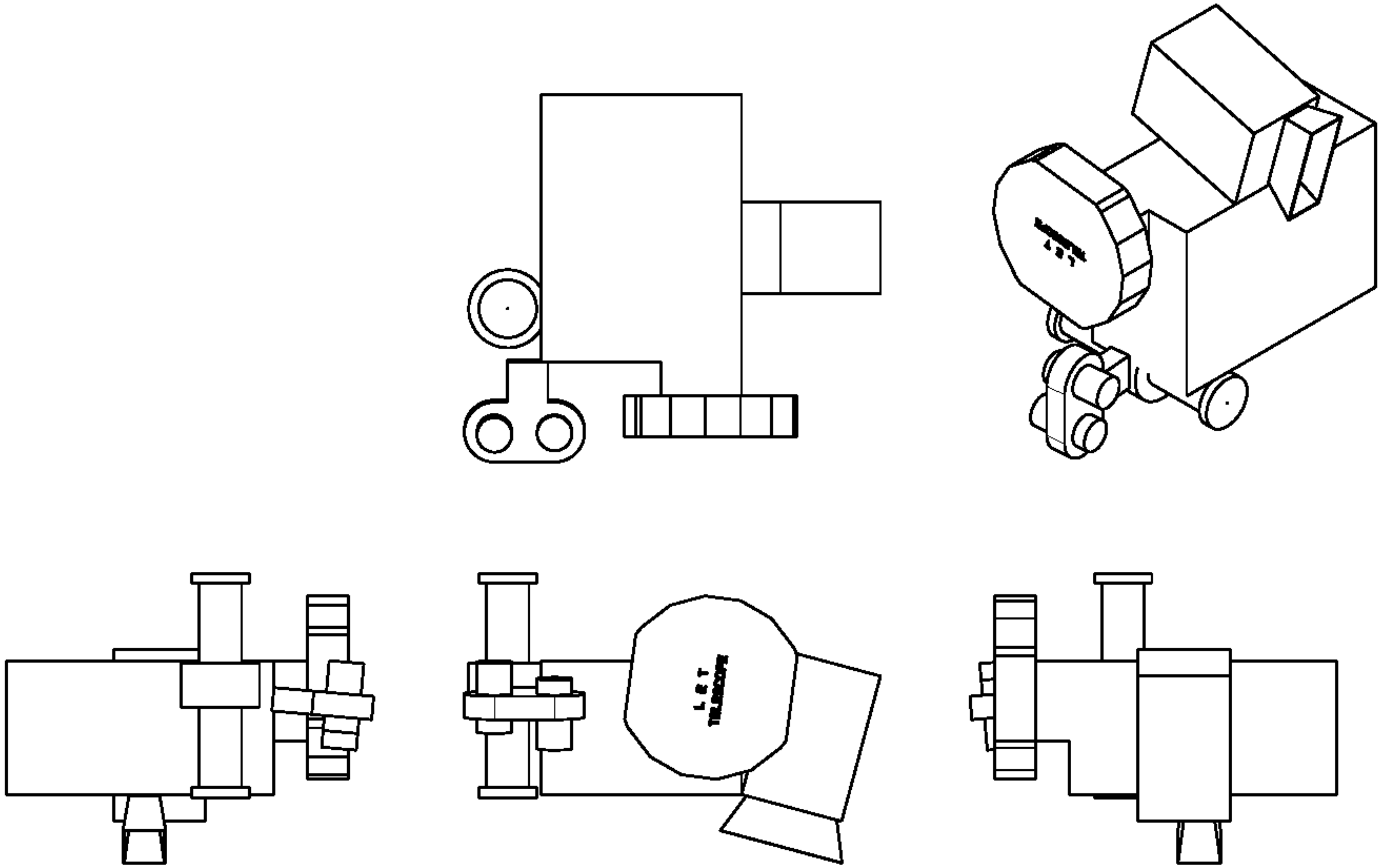
SWEA/STE/MAG Boom



SEP, Trailing Spacecraft



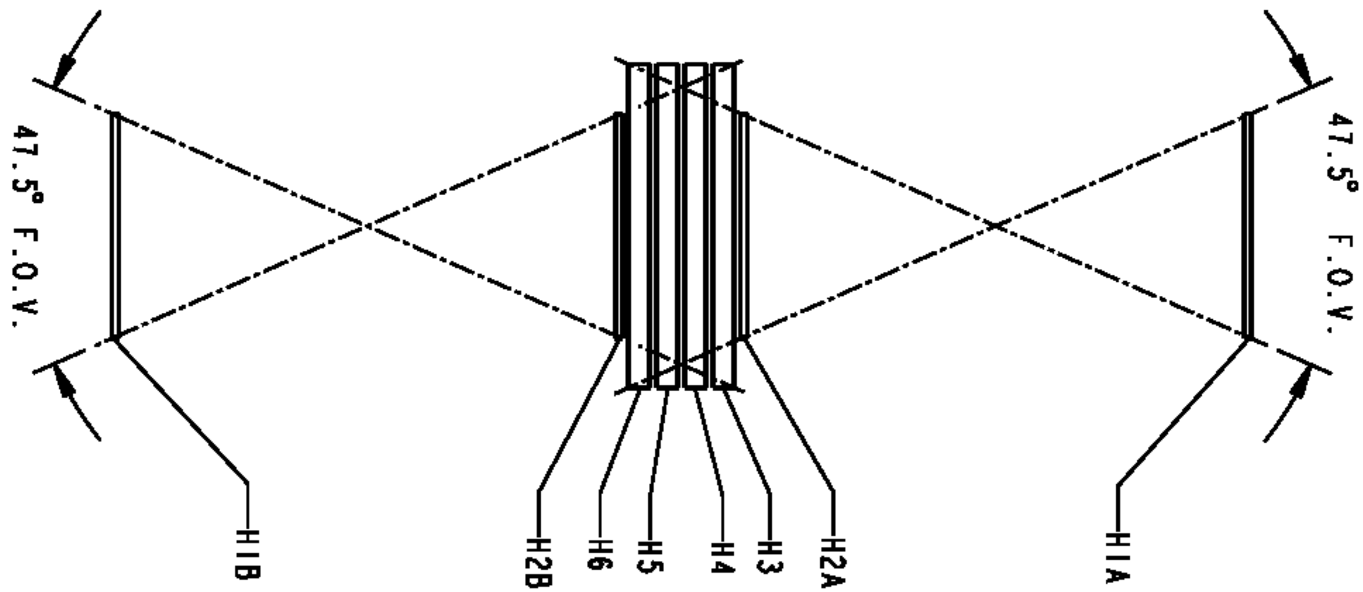
SEP, Leading Spacecraft



SEP High Energy Telescope (HET)

DETECTOR CHART

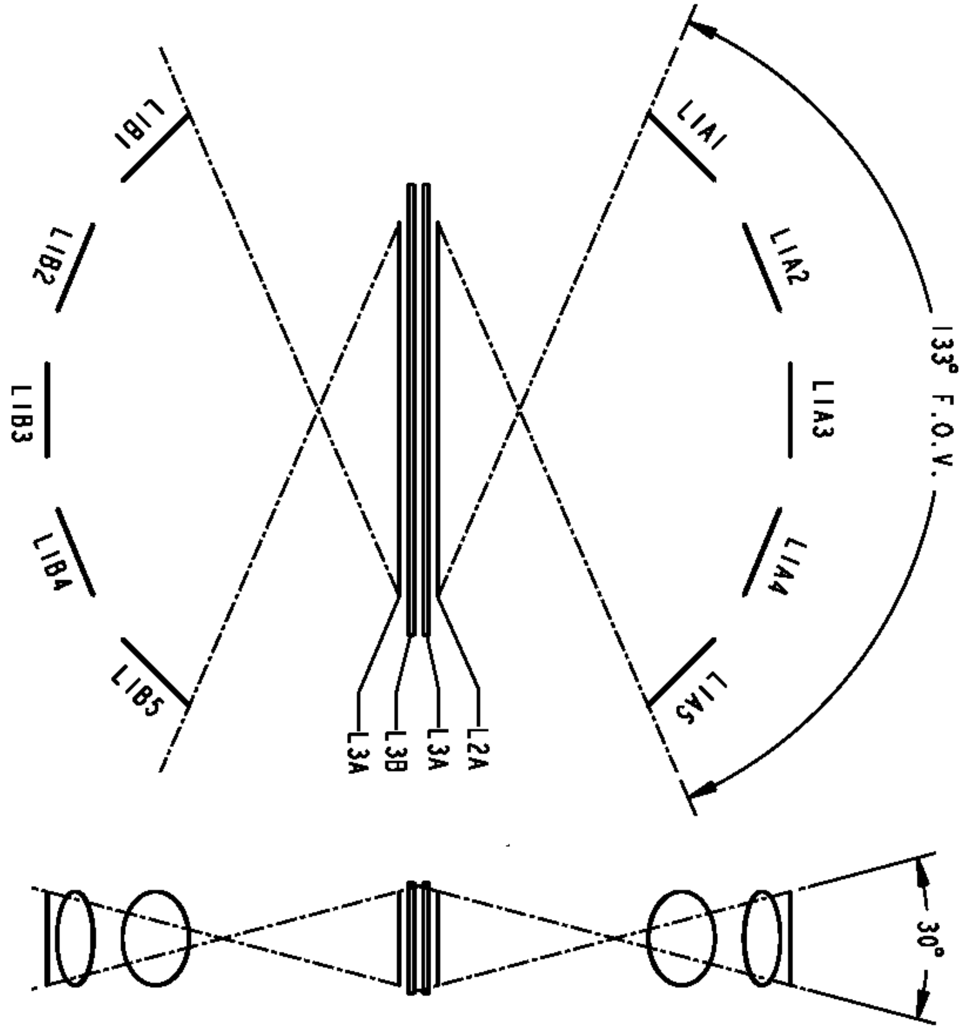
REF.	DESCRIPTION
H1_ & H2_	8.0 cm2 x 1.0mm
H3 THRU H6	17.0 cm2 x 3.0mm



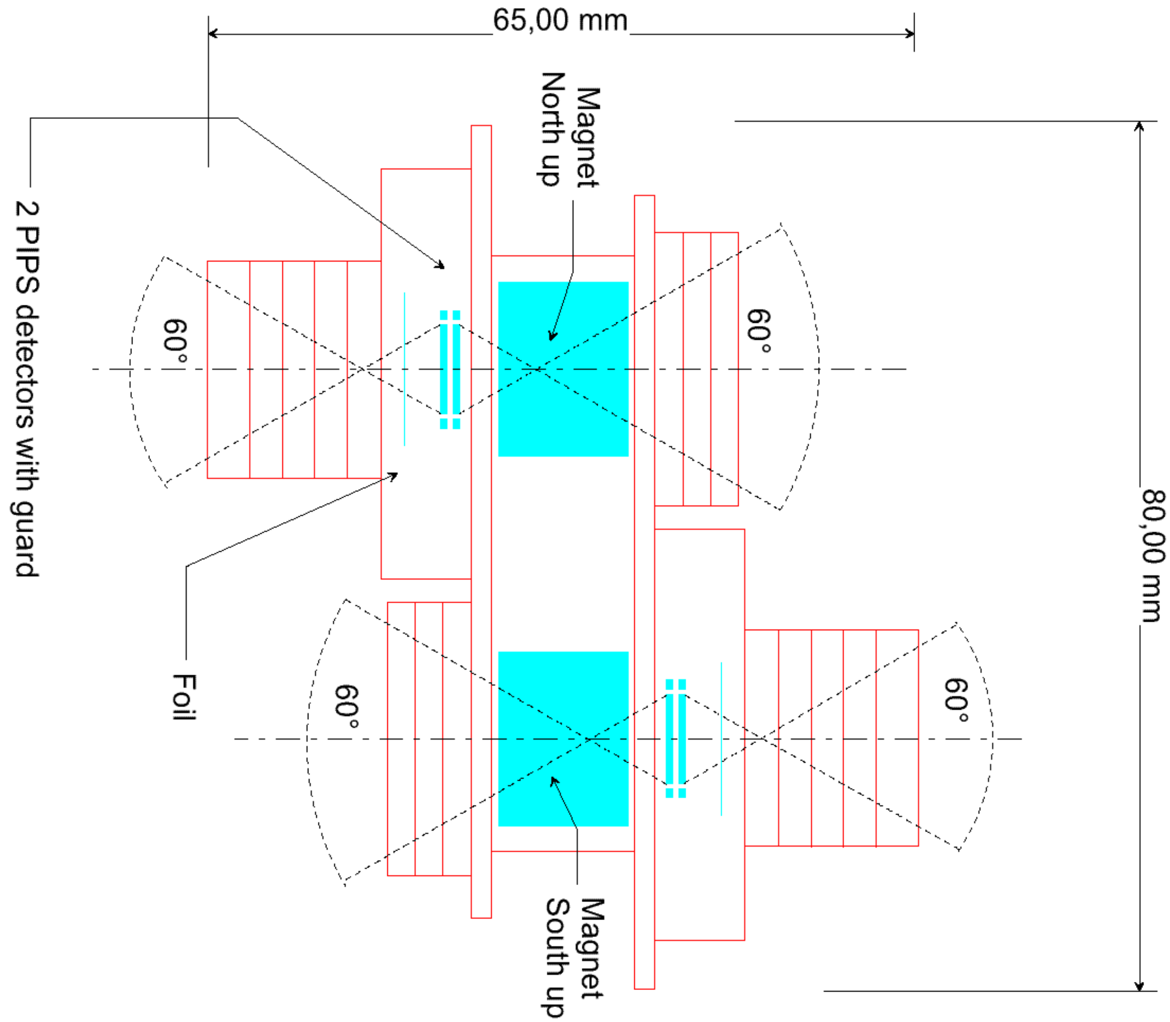
SEP Low Energy Telescope (LET)

DETECTOR CHART	
REF.	DESCRIPTION
L1..	2.0cm2 x 0.015mm
L2..	16mm x 64mm x 0.05mm*
L3..	20mm x 77mm x 1.0mm

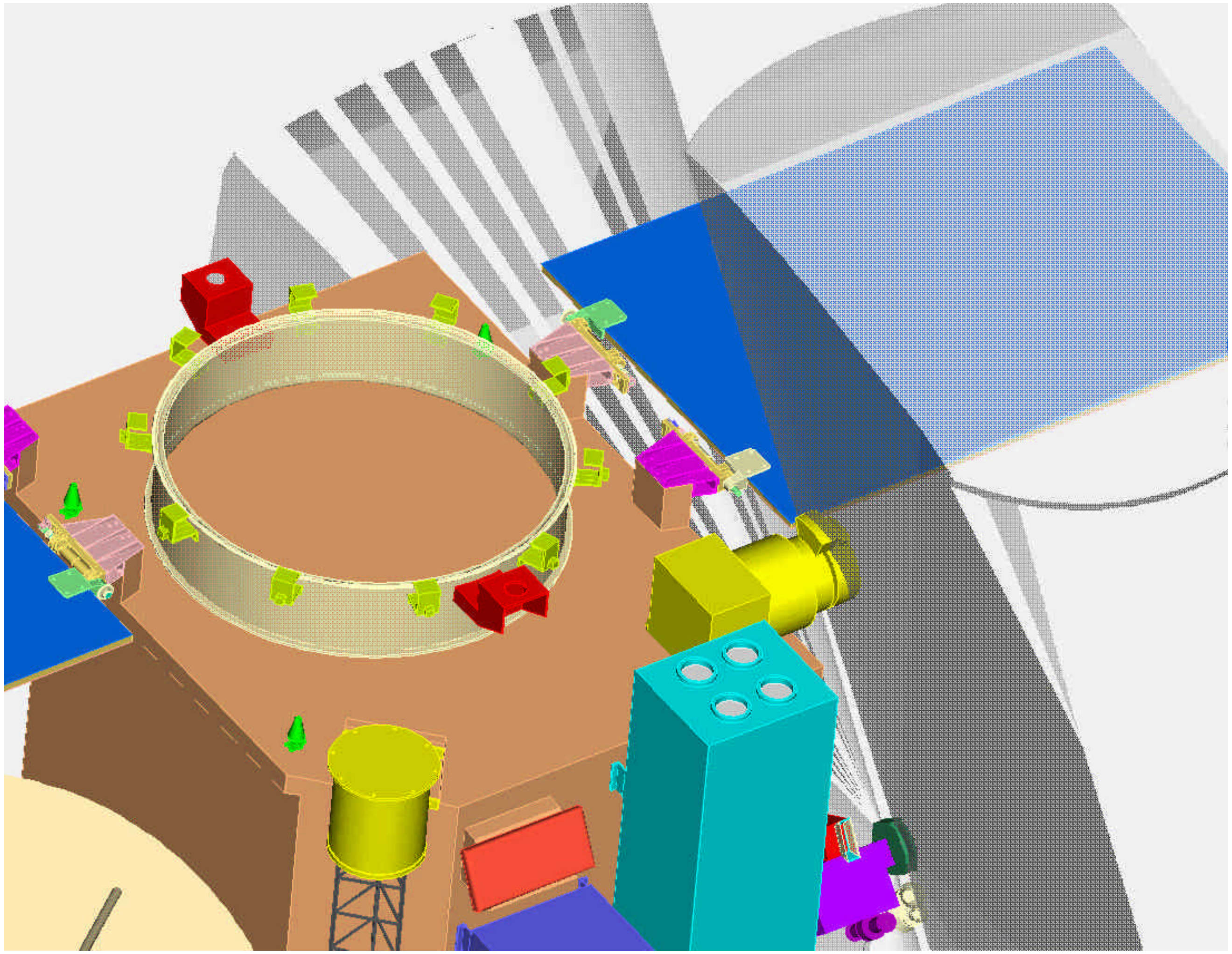
* SEGMENTED TO 10 6.4mm X 16mm SECTIONS



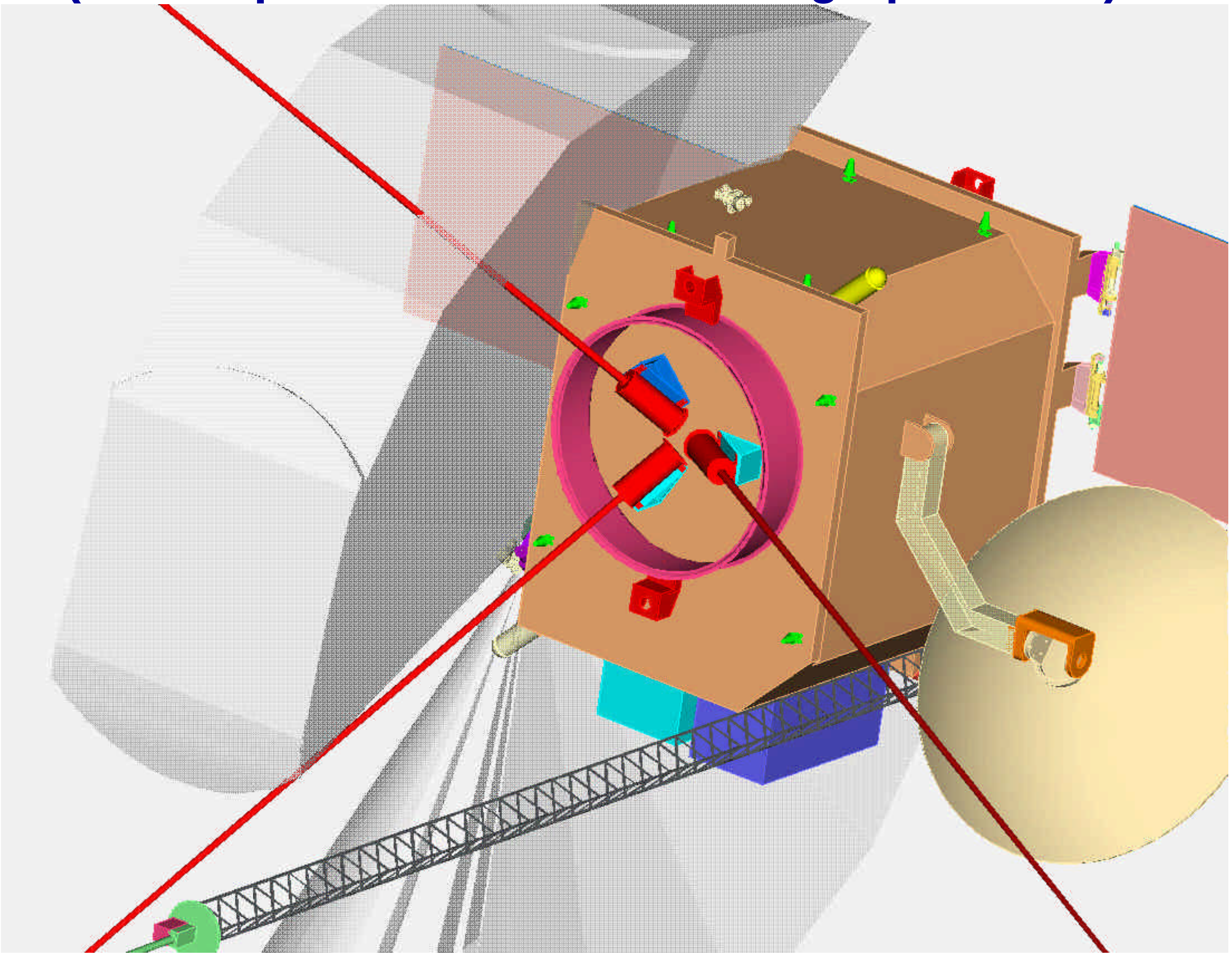
SEP Solar Energetic Particle Telescope (SEPT), 1 of 2



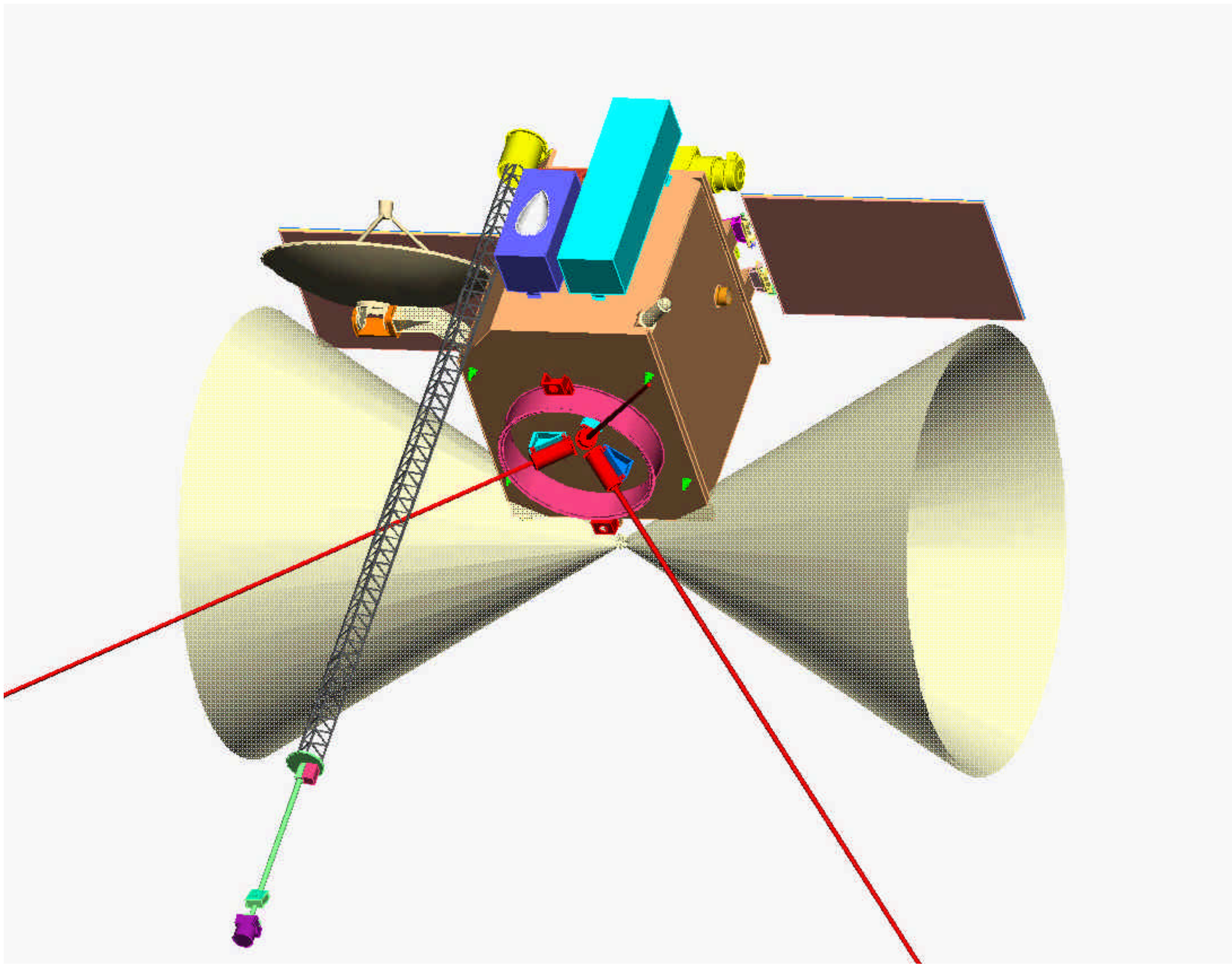
Trailing SEP/LET FOV Forward FOV Impingement with the front of PLASTIC



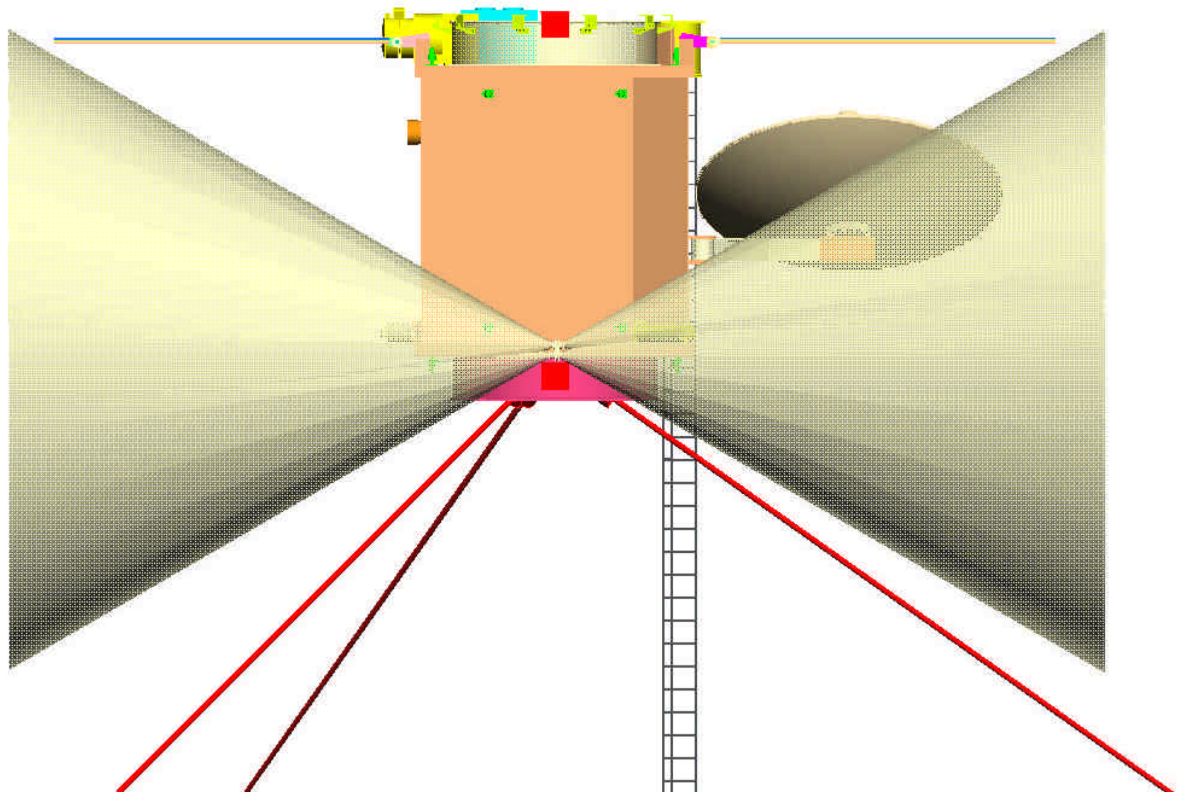
Leading SEP/LET FOV Impingement with the Spacecraft body (similar problem with the Trailing Spacecraft)



SEPT-NS FOV Impingement



SEPT-NS FOV Clears Solar Array



SEP Dynamic Envelope Constraint