STEREO
IMPACT

Performance Specification

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Document Revision Record

Rev.	Date	Description of Change	Approved By
A	2001-Apr-5	Preliminary Draft	-
B	2001-May-3	Inputs from Reinhold for SEPT	-
C	2001-Jun-22	Inputs from Walpole for SIT	-
D	2001-Jul-9	Inputs from Larson for SWEA, STE	-
E	2001-Jul-17	Fix some typos, update SIT timing TBD, add HET/LET requirements	-
F	2001-Sep-7	Update MAG Requirements Add level 1 requirements	-
G	2002-Apr-8	Update to match latest level 1 requirements from the MRD rev B; reference MRD rather than listing the higher level requirements.	-
H	2002-May-9	Additional information added and corrections made in response to Project requests.	
I	2003-April-1	Add boom requirements	

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1. Introduction

This specification describes the performance goals and requirements for the IMPACT investigation on the STEREO mission. These specifications are at the derived science requirements level, listing verifiable instrument performance requirements. It does not include the derived engineering requirements (mass, power, interfaces, etc.), which are largely covered by documents like the Spacecraft ICD.

1.1. *Document Conventions*

In this document, TBD (To Be Determined) means that no data currently exists. A value followed by TBR (To Be Resolved) means that this value is preliminary. In either case, the value is typically followed by a code such as UCB indicating who is responsible for providing the data, and a unique reference number.

1.2. *Applicable Documents*

The following documents include drawings and STEREO Project policies. All documents and drawings can be found on the Berkeley STEREO/IMPACT FTP site:

http://sprg.ssl.berkeley.edu/impact/dwc/

1. PhaseAReport/ - Phase A Report, split into a number of files
2. Project/Project/460-RQMT-001-MRDrevB – Mission Requirements Document

2. Science Requirements

The top-level science requirements and their flow-down to the IMPACT instrument are listed in the STEREO Mission Requirements Document (reference 2). From these requirements, the instrument performance requirements below have been extracted or derived.

A listing of the science objectives for each instrument is summarized below. The performance requirements, by instrument, are listed in Section 3.

2.1. *MAG Science*

- **Identify ICMEs at one or two of the STEREO sites, providing information on their global scale and uniformity, including their associated interplanetary shocks (strength, surface orientations), compressed solar wind sheaths, and internal field configurations (e.g. flux rope or other, flux rope orientation, size, and handedness, and ejecta flux content)**
  - ***for relating to the solar observations and determining potential geoeffectiveness***
- **Define ambient solar wind conditions at the two spacecraft, including stream structures and interfaces, and heliospheric current sheet crossings**
  - ***for relating to solar observations, and determining potential geoeffects from high speed streams and stream interfaces alone, as well as the***

effects of the ICME on ambient conditions, and ambient conditions on the ICME

- **Organize local particle (solar wind and SEP) distribution functions including IMPACT/SWEA, STE, and SEP electrons, and PLASTIC and IMPACT/SEP ions.**
  - ***SWEA heat flux electrons for inferring field topology and connections to the Sun, STE electrons for inferring field connections to active regions, PLASTIC solar wind and ICME ions for deducing plasma ion sources, and SEPs from SIT,SEPT,LET,HET for deducing SEP origin, acceleration, and propagation processes***
- **Determine properties of low frequency waves in the interplanetary medium**
  - ***for characterizing waves at ICME shocks that play a role in SEP acceleration and propagation, and large Alfven wavetrains that sometimes accompany ICMEs and produce geoeffects of their own***
- **Provide a measure of one of the fundamental heliospheric MHD parameters**
  - ***for comparisons with 3-D models of shocks and other solar wind and ICME features that will be used to connect the SECCHI observations to the STEREO in-situ observations***

2.2. *SWEA Science*

SWEA measures the 3-D electron distribution function from ~0-3000 eV with nearly complete (90% of 4p) angular coverage. This energy range includes the thermal core population (<60 eV) and the highly anisotropic, suprathermal halo population (>60 eV) that carries the majority of the solar wind heat flux. Some specific goals of SWEA are to:

- **Provide direct comparison of in-situ density measurements with coronagraph images.** SECCHI coronagraph images are a measure of column integrated electron density and can be compared to electron density measured in-situ by SWEA on the complementary STEREO spacecraft.
- **Determine magnetic field topology.** Suprathermal (>60 eV) electrons are excellent tracers of magnetic field topology. For example, Bi-directional streaming is a signature of magnetic field lines that are connected at both ends to the Sun.
- **Provide a remote probe of coronal electron temperature.** Measurements of the slope of the distribution function at electron energies > 100 eV provide a tool for remote sensing of the inner coronal electron temperature.
- **Identify ICMEs at one or both of the STEREO spacecraft locations.** Bi-directional electron distribution are one of the primary signatures of ICMEs. These measurements are also useful for identifying ambient solar wind conditions such as stream structures, interfaces and heliospheric current sheet crossings.
- **Provide measurements of fundamental plasma parameters.** Density, velocity, electron temperature and pressure measurements are critical for comparison with 3-D models of solar wind and ICME propagation and relating to solar observations and determining potential geoeffectiveness.

2.3. *STE Science*

STE measures electron fluxes in the 2-100 keV energy range where shock acceleration and flare-site acceleration begin to become important sources.. Some specific goals of SWEA are to:

- **Identify the solar source and magnetic footpoints of ICMEs.** Impulsively accelerated electrons detected in an ICME can be tracked by the type III radio burst they produce from 1 AU back to the Sun, where the parent flare-like event can be imaged.
- **Determine the length of field lines in ICMEs.** The field line length can be obtained by analyzing the velocity dispersion (the arrival of the faster electrons first) in impulsive events.
- **Probe particle acceleration near the Sun in both impulsive and gradual (CME-related) solar energetic particle (SEP) events.** Energy loss effects in traversing the corona will show up in the STE energy range, thus providing the column depth to the acceleration region. Velocity dispersion studies of STE electrons and SEP ions probe the timing and heights of the ion and electron acceleration.
- **Probe the in situ acceleration of electrons by ICME shocks waves, and identify the shock parameters that lead to type II radio emission.** The ICME shock accelerated ~1-10 keV electrons produce the type II radio emission used to track ICMEs from the Sun to 1 AU. STE measurements will probe the in situ acceleration of electrons by ICME shocks and determine the shock parameters that lead to type II radio emission.
- **Identify the source (presently unknown) of the superhalo (~1-100 keV) electrons that are always present in the interplanetary medium.** STE's high sensitivity will enable unambiguous measurements of angular distributions and spectra to identify the source.

2.4. *SEP Science*

- Solar Energetic Particle (SEP) studies with STEREO have four main objectives:
  - To understand how and where CMEs accelerate charged particles
  - To characterize properties of the subset of CMEs that do accelerate particles
  - To complement STEREO images by sensing remotely ICME and magnetic field structures
  - To develop tools for improved forecasts of large SEP events and/or to warn of their onset
- To address these objectives requires:
  - Composition over a broad energy/intensity range
  - Excellent temporal resolution
  - Spatially separated spacecraft
- Composition data from LET, SIT and HET will:
  - Distinguish flare-accelerated & CME-shock accelerated particles
  - Identify seed populations (coronal, solar wind, suprathermal ions, pickup ions)

    - Investigate the physics of particle acceleration with ions of differing charge/mass ratios (Fe/O, 3He/4He,22Ne/20Ne, p/e)
    - Investigate how proton-generated waves throttle escape of various species from the shock
- Broad energy coverage (HET/LET/SIT for composition; SEPT for protons / electrons) will:
    - Allow comparison of measured energy spectra with acceleration models
    - Provide a larger event sample (from small flare-related events to large CME-driven events)
    - Investigate acceleration processes continuously from injection energies to their upper limit
    - Measure 10 to 100 MeV/nucleon proton & alpha-particle intensities of space weather interest
    - Provide a broad range of particle intensities for the STEREO Beacon Mode
- Spatially separated measurements are needed to:
    - Investigate the spatial extent of acceleration along the shock
    - Measure in situ interplanetary parameters of CMEs that accelerate particles seen by trailing S/C
    - Develop tools to enable forecasts of SEP radiation hazards with future interplanetary networks
- In summary, SEP IMPACT Measurements will address key objectives for STEREO and Living with a Star:
    - Provide "ground-truth" for interpreting CME images in terms of energetic-particle production and transport, and for investigating the consequences of CMEs
    - Provide the tools to understand and eventually forecast large solar particle events
    - Provide key data for the STEREO Beacon Mode
    - Address important LWS goals that include investigating the solar-cycle and spatial dependence of solar-particle events and mitigating solar-particle risks

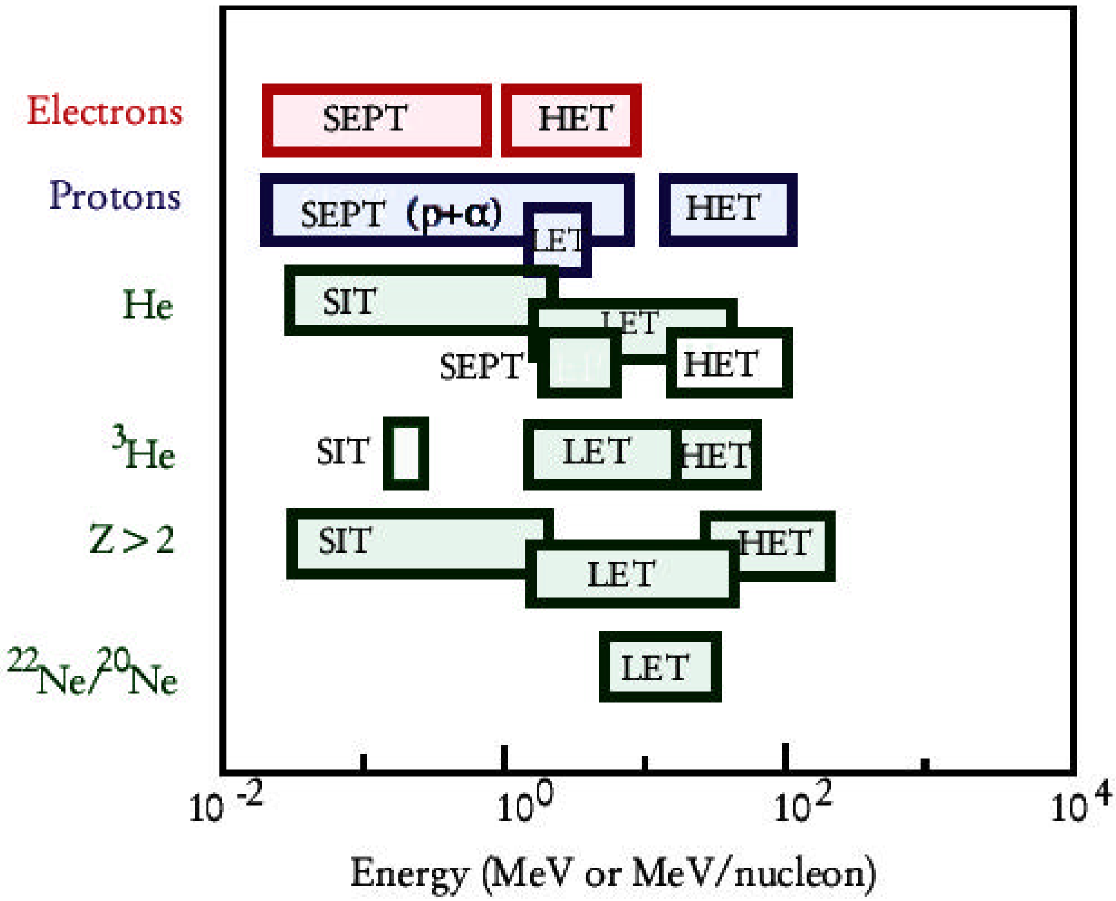

Figure 2-1 IMPACT & PLASTIC Energy Coverage

3. Performance Requirements

The requirements are listed below by instrument. The table lists both the desired goal as well as the minimum acceptable requirement. Inability to meet goals within the allocated resources must be waived by the Principal Investigator; inability to meet requirements must be waived by the STEREO Project office. All of these requirements are imposed on the instruments for both spacecraft.

3.1. *MAG Requirements*

Description	Goal	Requirement	Source
Noise level	0.01 nT	0.05nT	Derived from MRD 4.7(K) and solar wind charateristics
Absolute Accuracy	+/- 0.1 nT	+/-0.1nT	MRD 4.7(K)
Range	+/-512 nT, +/-65536 nT	+/-512 nT	MRD 4.7(K)
Drift	+/-0.2 nT/yr	+/-0.2nT/yr	Derived from Absolute accuracy & MRD 4.6.2.6.1
Time Resolution	1/4 sec. 1/32 sec. (Burst)	1 sec	MRD 4.7(K)

3.2. *SWEA Requirements*

Description	Goal	Requirement	Source
FOV	360 x 130 degree	360 x 60 degrees	MRD 4.7(H,I,J)
Resolution	22.5 degree	45 degrees	MRD 4.7(H,I,J)
Energy	1 to 5000eV	20 to 1000eV	MRD 4.7(H,I,J)
Energy Resolution (Telemetry)	65%	100%	Derived from MRD 4.7(H,I,J) & solar wind characteristics
Geometric Factor	0.01 cm^2 ster E(eV)	0.001 cm^2 ster E(eV)	Derived from MRD 4.7(H,I,J) & solar wind characteristics
Max Count Rate (per 22.5 degree sector)	1E6 counts/sec	1E5 counts/sec	Derived from MRD 4.7(H,I,J) & solar wind characteristics
Time Resolution	1 minute (3D) to 2 seconds (moments, burst)	1 minute	MRD 4.7(H,I,J)

3.3. *STE Requirements*

Description	Goal	Requirement	Source
FOV	Two opposite 80 x 80 degree	60 x 60 degree	Derived from MRD 4.7(F,G) & solar wind characteristics
Resolution	80 x 20 degrees	60 x 20 degrees	Derived from MRD 4.7(F,G) & solar wind characteristics
Energy	2 - 100 keV	5 – 100 keV	MRD 4.7 (F,G)
Energy Resolution (Telemetry)	35%	100%	Derived from MRD 4.7(F,G) & solar wind characteristics
Energy Resolution (Electronic)	300eV FWHM	2keV	Derived from lower energy and resolution requirements above.
Geometric Factor	0.4 cm^2 ster	0.1 cm^2 ster	Derived from MRD 4.7(F,G) & solar wind characteristics
Background	<1c/s/detector	<30c/s /detector	Derived from MRD 4.7(F,G) & solar wind characteristics
Max Count Rate (per detector)	100,000 counts/sec	10,000 counts/sec	Derived from MRD 4.7(F,G) & solar wind characteristics
Time Resolution	16 seconds 2 seconds (burst)	1 minute	MRD 4.7 (F,G)

3.4. *SIT Requirements*

Description	Goal	Requirement	Source
FOV	17 x 44 degrees	17 x 44 degrees	Derived from MRD 4.7(F,G) & CME characteristics
Energy	30-2,000 keV/nuc He-Fe	30-2,000 keV/nuc He-Fe	MRD 4.7 (F,G)
Mass Resolution	0.85 AMU (^{16}O at 100keV/nuc)	0.85 AMU (^4He at 1MeV/Nuc)	Derived from MRD 4.7(F,G) & CME characteristics
Energy Resolution	20keV FWHM	35keV FWHM @ 22C	Derived from MRD 4.7(F,G) & CME characteristics
Geometric Factor	0.4 cm^2 ster	0.4 cm^2 ster	Derived from MRD 4.7(F,G) & CME characteristics
Background	10^{-2} events/sec in quiet time	10^{-2} events/sec during vac test	Derived from MRD 4.7(F,G) & CME characteristics
Max Event Rate	1000 events/sec	1000 events/sec	Derived from MRD 4.7(F,G) & CME characteristics
Time Resolution	1 Minute	15 Minutes	Derived from MRD 4.7(F,G) & CME characteristics

3.5. *SEPT Requirements*

Description	Goal	Requirement	Source
FOV	2 sets of oppositely directed 52 degree cones each for electrons and protons	2 sets for electrons and protons, each with: 2 oppositely directed view cones in-ecliptic, 2 oppositely directed view cones off-ecliptic, 45 degree full opening angle	Derived from MRD 4.7(F,G) & CME characteristics
Energy	20-400 keV electrons, 20-7000 keV protons	30-400 keV, electrons 30-2000 keV, protons	MRD 4.7(F,G)
Energy Resolution (Telemetry)	20% electrons, 20% protons	30%, electrons 30%, protons	Derived from MRD 4.7(F,G) & CME characteristics
Geometric Factor	0.52 cm^2 ster, electrons, 0.68 cm^2 ster, protons	0.4 cm^2 ster, electrons, 0.4 cm^2 ster, protons	Derived from MRD 4.7(F,G) & CME characteristics
Background	< 0.2 counts/s on ground, 20°C	< 2 counts/s on ground, 20°C	Derived from MRD 4.7(F,G) & CME characteristics
Max Event Rate	25,000 counts/s at 2.2 MeV 250,000 counts/s at 55 keV	25,000 counts/s at 2.2 MeV 250,000 counts/s at 55 keV	Derived from MRD 4.7(F,G) & CME characteristics
Time Resolution	60 sec	60 sec	Derived from MRD 4.7(F,G) & CME characteristics

3.6. *LET Requirements*

Description	Goal	Requirement	Source
FOV	2 oppositely directed 130 x 30 degree fans	2 oppositely directed 100 x 30 degree fans	Derived from MRD 4.7(F,G) & CME characteristics
Energy Range (MeV/nucleon)	H: 1.4 - 6 He: 1.4 - 13 O: 2.5 – 25 Fe: 2.5 - 50	H: 1.5 - 3 He: 1.5 - 13 O: 3 – 25 Fe: 3 - 25	MRD 4.7 (F,G)
Geometric Factor cm^2 ster	H, He: 0.9 6=Z=26: 4.5	H, He: 0.5 6=Z=26: 2	Derived from MRD 4.7(F,G) & CME characteristics
Element Resolution	Also resolve Na, Al, S, Ar, Ca	Resolve H, He, C, N, O, Ne, Mg, Si, Fe	Derived from MRD 4.7(F,G) & CME characteristics
^{4}He Mass Resolution	=0.25 AMU	=0.35 AMU	Derived from MRD4.7(F,G) & CME characteristics
Max Event Rate	5000 events/sec	1000 events/sec	Derived from MRD 4.7(F,G) & CME characteristics
Energy Binning	8 intervals per species for Z=2 4 intervals for H	6 intervals per species for Z=2 3 intervals for H	Derived from MRD 4.7(F,G) & CME characteristics
Species Binning	Add S, Ar, Ca	H, ^{3}He, ^{4}He, C, N, O, Ne, Mg, Si, Fe	Derived from Element Resolution above.
Time Resolution	1 minute H, He, 15 minutes Z=6 4 prioritized events/sec	15 minutes 1 prioritized event/sec	Derived from MRD 4.7(F,G) & CME characteristics
Beacon Telemetry:	1 minute for H, He, 6=Z=26	1 minute for H, He, 6=Z=26	Derived from MRD 6.7.1 & CME charateristics

3.7. *HET Requirements*

Description	Goal	Requirement	Source
FOV (full angle)	58 degree cone	50 degree cone	Derived from MRD 4.7(F,G) & CME characteristics
Energy Range (MeV/nucleon)	e: 1 - 8 H, He: 13 - 100 ^{3}He: 16 – 50 ~30 to 80 for 6 = Z = 26	1 – 6 13 – 40 16 – 40 ~30 to 80 for 6 = Z = 14	MRD 4.7(F,G)
Geometric Factor, cm^2 ster	0.7	0.5	Derived from MRD 4.7(F,G) & CME characteristics
Element Resolution, dZ (rms), for stopping particles	= 0.3 for 16 = Z = 26	= 0.2 for 1 = Z = 14	Derived from MRD 4.7(F,G) & CME characteristics
^{4}He Mass Resolution	=0.20 amu	=0.25 amu	Derived from MRD 4.7(F,G) & CME characteristics
Max Event Rate	5000 events/sec	1000 events/sec	Derived from MRD 4.7(F,G) & CME characteristics
Energy Binning	Eight intervals per species	Six intervals per species	Derived from MRD 4.7(F,G) & CME characteristics
Species Binning	Add 16 = Z = 26	H, ^{3}He, ^{4}He, 6=Z=14, Electrons	Derived from Element Resolution above.
Time Resolution	15 minutes 1 prioritized events/sec	15 minutes 0.3 prioritized event/sec	Derived from MRD 4.7(F,G) & CME characteristics
Beacon Telemetry:	1 minute H, He, e	1 minute H, He, e	Derived from MRD 6.7.1 & CME charateristics

4. Boom Performance Requirements

The IMPACT boom supports the MAG, SWEA, and STE instruments. Its primary requirements are:

- To separate MAG from the spacecraft to minimize stray spacecraft fields at the magnetometer
- To separate SWEA from the spacecraft to help clear its large field of view
- Provide a location for STE-U and STE-D with clear fields of view and good conditions for passive cooling

4.1. *Boom Science Requirements*

Description	Goal	Requirement	Source
Magnetic field	<1nT static, 0.05nT dynamic at the boom		MRD 4.7(K)
- MAG distance from spacecraft	>3m	3m	MRD 4.7(K) and typical spacecraft magnetic characteristics
- MAG distance from other boom-mounted instruments	>1m	1m	MRD 4.7(K) and recent experience with SWEA-like instrument
- MAG distance from boom harness	>20cm (center to center)	20cm	MRD 4.7 (K) and expected harness currents
- MAG mounting bracket material	Non-metallic	Non-metallic	MRD 4.7 (K) and thermal current issues
Instrument alignment (*)	<+/- 1 degree knowledge / alignment	+/- 1 degree knowledge	MRD 4.7(K)
SWEA FOV	Clear	>80% clear	MRD 4.7(H,I,J)
SWEA FOV	No sunlight in aperture	No sunlight in aperture during science modes	MRD 4.7(H,I,J), detector sensitivity to UV
Boom surface conductivity	<1V exposed voltage on boom	<10Kohms bulk, <10E8 ohms/square	MRD 4.7(H,I,J), electrostatics
STE FOV	Clear	Clear	MRD 4.7(F,G), Scattered light sensitivity
STE FOV	No sunlight in aperture, >2-bounce system	2-bounce system to detectors	MRD 4.7(H,I,J), detector sensitivity to UV
STE Thermal	<-50C	<0C	MRD 4.7(F,G), STE detector noise

(*) Includes <0.25 degree spacecraft allocation for mounting, attitude knowledge, etc., leaving 0.75 degrees for MAG sensor mounting, boom deployment repeatability, etc.

4.2. *Boom Performance Requirements*

In addition to the science requirements, there are a number of boom performance requirements captured in other requirements documents.

Description	Source
Boom Stiffness	IMPACT ICD, APL 7381-9012
Spacecraft Thermal, Mechanical, Electrical Interface	IMPACT ICD, APL 7381-9012
SWEA/STE/MAG Thermal requirements	IMPACT ICD, APL 7381-9012
Harness Shielding	EMC Requirements, APL 7381-9030
Magnetics	EMC Requirements, APL 7381-9030
Contamination	Contamination Requirements, APL 7381-9006 IMPACT Contamination Control Plan, TBD
Environmental	Environmental Requirements, APL 7381-9003
Performance Assurance	IMPACT PAIP
SWEA Instrument Interface	SWEAICD
MAG Sensor Interface	MAG_Sensor_ICD
Harness Spec	IMPACTHarnessSpec