STEREO
IMPACT

Requirements Verification / Validation Plan

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Rev.	Date	Description of Change	Approved By
A	2002-Jun-12	Preliminary Draft	-
B	2002-Jul-11	Add SEPT Verification plan Add LET Verification Plan	-
C	2002-Nov-14	Add MAG Verification plan	

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1. Introduction

This plan describes how the IMPACT team will verify that the IMPACT instrument suite how the IMPACT Instrument satisfies the instrument science objectives. Another document, the IMPACT Environmental Test Plan, describes verification that the instrument meets its environmental requirements. This plan is based on the instrument performance requirements as called out in the IMPACT Performance Requirements document.

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
3. Specifications/IMPACTPerformanceSpec– IMPACT Performance Requirements
4. Plans/IMPACTEnvTestPlan– IMPACT Environmental test plan
5. Plans/STEREO-IMPACT-PAIP– IMPACT Performance Assurance Implementation Plan

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 in the IMPACT Performance Requirements (reference 3).

3. Top-Level Requirements Validation

The following section describes how the instrument performance requirements are verified, mostly at the instrument level. This section describes the end-to-end validation testing.

The IMPACT suite consists of a number of instruments connected together through the SEP Central electronics and the IDPU as indicated in Figure 3-1. Most of the performance verification is done at the instrument level, without the IDPU or SEP Central present.

The interfaces between the instruments and the IDPU and SEP Central are via serial digital interfaces, and in some cases, low voltage and bias supply power, which are simulated by GSE during instrument level tests.

Full performance/calibration tests at the integrated suite levels cannot be made because these tests require special facilities. High Voltage supplies can also not be operated to full levels in air. At these times, test pulsers, radiation sources, cosmic rays, etc. shall be used to stimulate the instruments as close to the front end as possible to verify data flow and operation.

3.1. *SEP Suite Testing*

The SEP instruments shall come together with SEP Central, including the SEP Low Voltage and Bias supply, at Caltech. This shall verify the following:

- Functionality of the serial interfaces
- End-to-end data flow testing (as far as the SEP Central interface to the IDPU).
- Capability of SEP Central to handle the full SEP instrument suite without interference between instruments due to processor loading, etc.
- EMC self-compatibility of the SEP suite, including compatibility of the instruments with the flight SEP Low Voltage and Bias supplies

3.2. *Boom Suite Testing*

The Boom suite (SWEA, STE, Mag, Boom) shall come together with the IDPU at Berkeley for end-to-end testing. This testing shall verify:

- Functionality of the serial interfaces
- End-to-end data flow testing
- Capability of the IDPU to handle the boom suite without interference between instruments due to processor loading, etc.
- EMC self-compatibility of the boom suite, including compatibility of the instruments with the Boom and IDPU low voltage power converters.

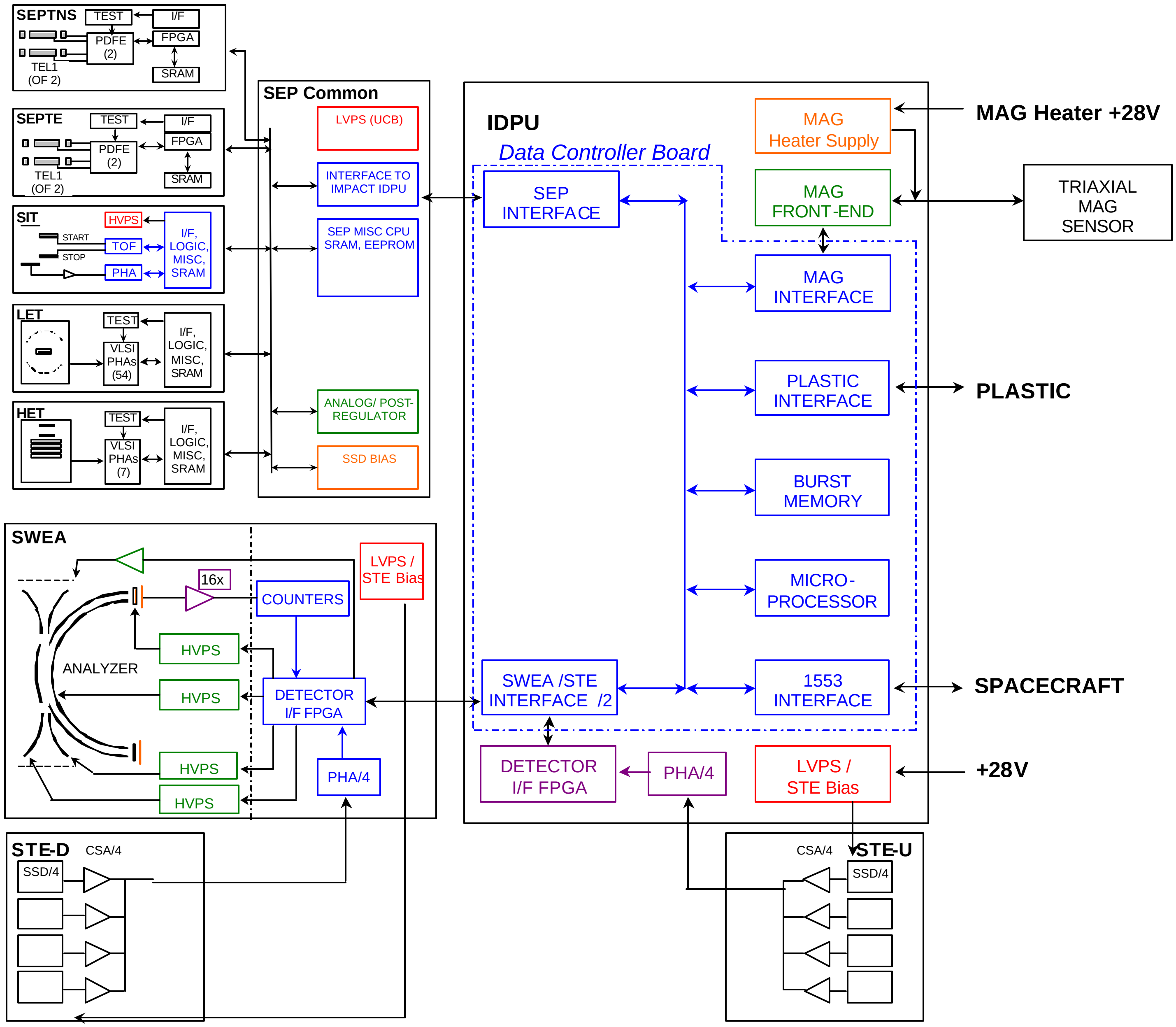
3.3. *Full Suite Testing*

The suite first comes together (as flight hardware) at the EMC test. The current plan is for PLASTIC to also be present for this test, but that is not being carried as a requirement. During this test we will verify the following:

- Functionality of the serial interfaces
- End-to-end data flow testing (as far as the spacecraft interface)
- Capability of the IDPU to handle the full instrument suite without interference between instruments due to processor loading, etc.
- EMC self-compatibility of the suite
- EMC Conducted and Radiated tests as called out in the Environmental Verification Plan (reference 4)

These tests are similar to those that will occur during the Spacecraft-level performance tests.

Figure 3-1 IMPACT Block Diagram



4. Instrument Performance Verification

The requirements are listed below by instrument. The table lists both the desired goal as well as the minimum acceptable requirement.

4.1. *MAG Requirements*

Description	Goal	Requirement	Verification
Noise level	0.01 nT	0.05nT	Operation in laboratory 4-layer magnetic shield with B<0.25 nT. Computation of noise spectrum from test data
Absolute Accuracy	+/- 0.1 nT	+/-0.1nT	Calibration against proton precession standard at GSFC Test Site – Electronics adjustments during electrical testing
Range	+/-512 nT, +/-65536 nT	+/-512 nT	Operation in laboratory coil system and MAG Test Site – Calibration against proton precession standard
Drift	+/-0.2 nT/yr	+/-0.2nT/yr	Short term test only – analytical verification from prior missions
Time Resolution	1/4 sec. 1/32 sec. (Burst)	1 sec	Integrated MAG/IDPU tests. Analog board has fixed rate of 32 samples/sec

4.2. ***SWEA Requirements***

Description	Goal	Requirement	Verification
FOV	360 x 130 degree	360 x 60 degrees	Calibration with electron gun at CESR
Resolution	22.5 degree	45 degrees	Calibration with electron gun at CESR
Energy	1 to 5000eV	20 to 1000eV	Calibration with electron gun at UCB for high energy end, with extrapolation to lower energies by analysis
Energy Resolution (Telemetry)	65%	100%	Calibration with electron gun at UCB for high energy end, with extrapolation to lower energies by analysis
Geometric Factor	0.01 cm^2 ster E(eV)	0.001 cm^2 ster E(eV)	Calibration with electron gun at CESR
Max Count Rate (per 22.5 degree sector)	1E6 counts/sec	1E5 counts/sec	Calibration with electron gun at CESR
Time Resolution	1 minute (3D) to 2 seconds (moments, burst)	1 minute	Analysis of telemetry allocation together with suite end-to-end verification test of data throughput

4.3. *STE Requirements*

Description	Goal	Requirement	Verification
FOV	Two opposite 80 x 80 degree	60 x 60 degree	Geometrical analysis of STE instrument together with spot checking during calibrations with an electron gun
Resolution	80 x 20 degrees	60 x 20 degrees	Geometrical analysis of STE instrument together with spot checking during calibrations with an electron gun
Energy	2 - 100 keV	5 – 100 keV	Calibrations with an electron gun and sources
Energy Resolution (Telemetry)	35%	100%	Calibrations with an electron gun and sources
Energy Resolution (Electronic)	300eV FWHM	2keV	Calibrations with an electron gun and sources
Geometric Factor	0.4 cm^2 ster	0.1 cm^2 ster	Calibrations with an electron gun and sources
Background	<1c/s/detector	<30c/s /detector	No-source background measurements
Max Count Rate (per detector)	100,000 counts/sec	10,000 counts/sec	Calibrations with an electron gun and sources
Time Resolution	16 seconds 2 seconds (burst)	1 minute	Analysis of telemetry allocation together with suite end-to-end verification test of data throughput

4.4. *SIT Requirements*

Description	Goal	Requirement	Verification
FOV	17 x 44 degrees	17 x 44 degrees	Geometrical analysis of SIT telescope, thin foil and solid state detector size.
Energy	30-2,000 keV/nuc He-Fe	30-2,000 keV/nuc He-Fe	Analysis of thin foil thickness (from manufacturer's specification), solid state detector threshold, and dynamic range of solid state detector energy amplifier and time-of-flight system. Spot-checks of performance done with radioactive alpha-sources, and ion beam calibration at Brookhaven Tandem Van de Graaff.
Mass Resolution	0.85 AMU (^{16}O at 100keV/nuc)	0.85 AMU (^{4}He at 1MeV/Nuc)	Laboratory calibration with radioactive alpha sources (energy approx 1 MeV/nucleon)
Energy Resolution	20keV FWHM	35keV FWHM @ 22C	Pulser calibration of energy system, along with calibration using radioactive alpha sources.
Geometric Factor	0.4 cm^2 ster	0.4 cm^2 ster	Geometrical analysis of SIT telescope, thin foil and solid state detector size.
Background	10^{-2} events/sec in quiet time	10^{-2} events/sec during vac test	Observe background event rate during lab vacuum tests without source.
Max Event Rate	1000 events/sec	1000 events/sec	Pulser calibration of instrument, and calibration at tandem Van de Graaff at Brookhaven National Lab.
Time Resolution	1 Minute	15 Minutes	Analysis of instrument bit rate and telemetered rate table size.

4.5. *SEPT Requirements*

Description	Goal	Requirement	Verification
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	Geometrical analysis of SEPT telescope, collimator aperture, magnet air gap, thin foil, and solid state detector size.
Energy	20-400 keV electrons, 20-7000 keV protons	30-400 keV, electrons 60-2000 keV, protons	Analysis of vector field of magnetic remanence with point charge model approach. Spot-checks to verify analytical calculations. Measurement of foil thickness with alpha-spectrometer (50 nm resolution). Mathematical model of SEPT telescope (GEANT Monte-Carlo-Simuation). Verification of model with ion-source (up to 300 keV) at HMI, Tandem Van de Graaff (up to 7 MeV) at HMI, conversion electrons (up to 1 MeV) with radioactive sources.
Energy Resolution (Telemetry)	20% electrons, 20% protons	30%, electrons 30%, protons	Measurement with cosmic ray muons, radioactive sources, proton beam, pulser calibration.
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	Geometrical analysis of SEPT telescope, collimator aperture, magnet air gap, thin foil, and solid state detector size. Monte-Carlo-Simulation to determine telescope response as function of energy and incidence angle.
Background	< 0.2 counts/s on ground, 20°C	< 2 counts/s on ground, 20°C	Measurement of background event rate during lab vacuum tests without source.
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	Pulser calibration of instrument, calibration at tandem Van de Graaff at HMI (Hahn-Meitner-Institut, Berlin).
Time Resolution	60 sec	60 sec	Analysis of instrument telemetry data, comparison with source strength measurements in lab.
Beacon Telemetry	e: 4 energy windows p: 4 energy windows	e: 4 energy windows p: 4 energy windows	Analysis of beacon telemetry data, comparison with instrument telemetry data.

4.6. ***LET Requirements***

Description	Goal	Requirement	Verification
FOV	2 oppositely directed 130 x 30 degree fans	2 oppositely directed 100 x 30 degree fans	Geometrical analysis of LET instrument coupled with laboratory mapping of solid state detector areas.
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	Pulser and alpha-particle calibrations coupled with detector thickness measurements and heavy-ion range-energy relations. Verification at particle accelerator.
Geometric Factor cm^2 ster	H, He: 0.9 6=Z=26: 4.5	H, He: 0.5 6=Z=26: 2	Geometrical analysis of LET instrument coupled with laboratory mapping of solid state detector areas.
Element Resolution	Also resolve Na, Al, S, Ar, Ca	Resolve H, He, C, N, O, Ne, Mg, Si, Fe	Alpha-particle measurement of detector thickness uniformity coupled with Monte Carlo simulations. Final verification at particle accelerator.
^{4}He Mass Resolution	=0.25 AMU	=0.35 AMU	Calibrations with alpha particle source and electronic pulser aided by analysis.
Max Event Rate	5000 events/sec	1000 events/sec	Bench tests with pulser; verification at particle accelerator.
Energy Binning	8 intervals per species for Z=2 4 intervals for H	6 intervals per species for Z=2 3 intervals for H	Pulser and alpha-particle calibrations supplemented by Monte-Carlo simulations. Verification at particle accelerator.
Species Binning	Add S, Ar, Ca	H, ^{3}He, ^{4}He, C, N, O, Ne, Mg, Si, Fe	Pulser and alpha-particle calibrations supplemented by Monte-Carlo simulations. Verification at particle accelerator.
Time Resolution	1 minute H, He, 15 minutes Z=6; Telemeter 4 prioritized events/sec	15 minutes 1 prioritized event/sec	Pulser and alpha-particle calibrations. Analysis of telemetry allocation and event formats supplemented by pulser calibrations. Verify end-to-end data throughput at particle accelerator.
Beacon Telemetry:	1 minute for H, He, 6=Z=26	1 minute for H, He, 6=Z=26	Pulser and alpha-particle calibrations. Final verification at particle accelerator.

4.7. ***HET Requirements***

Description	Goal	Requirement	Verification
FOV (full angle)	58 degree cone	50 degree cone	
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	
Geometric Factor, cm^2 ster	0.7	0.5	
Element Resolution, dZ (rms), for stopping particles	= 0.3 for 16 = Z = 26	= 0.2 for 1 = Z = 14	
^{4}He Mass Resolution	=0.20 amu	=0.25 amu	
Max Event Rate	5000 events/sec	1000 events/sec	
Energy Binning	Eight intervals per species	Six intervals per species	
Species Binning	Add 16 = Z = 26	H, ^{3}He, ^{4}He, 6=Z=14, Electrons	
Time Resolution	15 minutes 1 prioritized events/sec	15 minutes 0.3 prioritized event/sec	
Beacon Telemetry:	1 minute H, He, e	1 minute H, He, e	