# STEREO

# *IMPACT*

## Performance Assurance Implementation Plan (PAIP)

STEREO-IMPACT-PAIP_B.doc
Version B – 2001-Jun-25

David Curtis, UCB IMPACT Project Manager

## Document Revision Record

| Rev. | Date | Description of Change | Approved By |
|---|---|---|---|
| A | 2000-July-27 | Phase A Report Draft | - |
| B | 2001-June-25 | Inputs from Project | |
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# 1. GENERAL

## 1.1. *Basis and Scope of the Plan*

This document has been written in response to the Draft STEREO Safety, Reliability & Quality Assurance Requirements document (November 1999), as called out in the Phase A Statement of Work.

The STEREO IMPACT (In situ Measurements of Particles and CME Transients) investigation shall provide a suite of particle instruments for the NASA STEREO mission. The IMPACT project is an international effort of several universities, laboratories, and NASA. The Principal Investigator (PI) for IMPACT is Dr. Janet Luhmann at the University of California at Berkeley (UCB), and the IMPACT Project Manager (PM) is David Curtis, also at UCB. Note that the term PI in this document refers to Dr. Luhmann or a designated member of the IMPACT team under her authority. The allocation of hardware development responsibilities amongst the team is called out in the STEREO/IMPACT Phase A Report. This PAIP covers that part of the development effort performed at UCB. Other NASA-funded institutions providing IMPACT flight hardware (Caltech, GSFC, UMd) shall conform to this PAIP. Non-NASA-funded institutions (foreign Co-Investigators) shall meet the Performance Assurance requirements called out by their funding agency, and so are generally not covered by the PAIP. Short descriptions of the Performance Assurance plans for European Co-Investigators providing flight hardware are included in Appendix B of this document.

## 1.2. *General Requirements*

The PI for the STEREO IMPACT instrument suite will establish an organized program which will demonstrate that the design meets the functional requirements, including margins, has been manufactured properly and that it will operate properly in association with other project components. This will be accomplished by conducting analyses, tests and inspections.

The performance assurance program will encompass flight equipment, critical GSE, Flight Software and spare flight equipment. This plan will be used by the PI and all Co-investigators who fabricate or test such equipment. This plan does not apply to ground support, mission operation, data analysis equipment or software except where specifically called out.

## 1.3. *Use of Previously Designed, Fabricated, or Flown Hardware*

Any previously designed or fabricated section of the hardware used on IMPACT will be subject to the PA requirements of this PAIP.

## 1.4. *Flow-Down of PA Requirements*

The PI will ensure that all vendors and subcontractors who supply hardware for the IMPACT instrument suite will meet applicable PA/QA requirements.

### 1.5. *Surveillance*

The work activities, operations, and documentation performed by NASA funded IMPACT institutions and their suppliers are subject to evaluation, review, audit, and inspection by government-designated representatives from GSFC, the Government Inspection Agency (GIA), or an independent assurance contractor (IAC). GSFC will delegate in-plant responsibilities and authority to those agencies via a letter of delegation, or the GSFC contract with the IAC.

The PI and/or subcontractor, upon request, shall provide government assurance representatives with documents, records, and equipment required to perform their assurance and safety activities. The PI shall also provide the government assurance representative(s) with an acceptable work area within developer facilities.

### 1.6. *SR&QA Verification*

The PI will provide GSFC or their representative with any documents and records outlined in the PAIP upon request.

### 1.7. *Applicable Documents (Appendix A)*

To the extent referenced herein, applicable portions of the documents and revision levels listed in Appendix A form a part of this document.

# 2. ASSURANCE REVIEW REQUIREMENTS

## 2.1. *General Requirements*

The PI will support a series of system-level design reviews that are conducted by an independent review team. The reviews will cover all aspects of the flight hardware, critical ground support hardware, flight software, and operations. In addition the PI will support informal subsystem-level engineering peer reviews as required by the Project.

## 2.2. *GSFC Flight Assurance Review Requirements*

For each system-level review, the Project Manager will:

- Organize an oral presentation of materials from the instrument development team to the review team. Preliminary copies of the viewing material will be furnished to the review team one week before the review, with a final version furnished at the time of the review.
- Support splinter review meetings resulting from the major review.
- Produce written responses to recommendations and action items resulting from the review.

## 2.3. *Flight Assurance Review Program*

The PI will support the following design reviews:

a. A Preliminary Design Review (PDR) which is to occur when the preliminary design is completed.
b. A Critical Design Review (CDR) which occurs before the bulk of the flight fabrication begins.
c. Pre-Environmental Review (PER) which occurs after the instrument suite is complete and before the full environmental tests are performed.
d. A Pre-Shipment Review (PSR) which occurs prior to shipping the instrument suite to the spacecraft for integration.
e. A Flight Readiness Review (FRR) which occurs when the spacecraft is at the launch facility. This is primarily a mission review with some instrument team input.
f. An Operations Readiness Review (ORR). This is primarily a mission review with some instrument team input.

In addition the PI will support Project-organized instrument subsystem peer reviews as required.

# 3. PERFORMANCE VERIFICATION REQUIREMENTS

## 3.1. *General Requirements*

A Performance Verification program will be conducted to ensure that the flight hardware meets the mission requirements. The program consists of a series of functional demonstrations, calibrations, analyses, physical measurements, and environmental tests which simulate the environments encountered during handling and transportation, pre-launch, launch and flight. All flight hardware will comply with the requirements of this PAIP. In the event that spare instrumentation is used, it will be verified prior to flight.

The applicable environmental verification program is described in GEVS-SE, as modified by environmental test specifications provided by STEREO Project (APL STEREO Document 7381-9003) based on system-level information.

## 3.2. *Documentation Requirements*

The IMPACT Project Manager will be responsible for managing the collection and distribution of verification documentation. This documentation will include a Verification Matrix, Environmental Test matrix, Verification Procedures, and Verification Reports. Verification documentation shall be available on request, and shall be summarized at design reviews.

### 3.2.1. Verification Matrix

The Verification Matrix shall show the flow-down of science and mission requirements and the method of verification for each requirement.

### 3.2.2. Environmental Test Matrix

The Environmental Test Matrix shall summarize the environmental tests to be performed at each level of assembly. Test levels, cycles, and special provisions will be called out.

### 3.2.3. Verification Test Procedures

Verification Test Procedures will be developed for all tests conducted at the component level and above. Such procedures will be at least a lab notebook level of formality.

### 3.2.4. Verification Test Report

A test report will be generated for each test at the component level and above. This report will show the degree to which the test objectives were met, how well the data correspond to the expected results, and any other significant findings. They will include as-run procedures and test data. Such reports shall be at least a lab notebook level of formality.

## 3.3. *Demonstration of Failure-Free Operation*

At the time of delivery of flight hardware to spacecraft integration, it shall have demonstrated trouble-free operation for at least 100 hours without significant change to the hardware.

# 4. SAFETY

## 4.1. *General*

The PI shall plan and implement a system safety program that accomplishes the following:

a. Identifies and controls hazards to personnel, facilities, support equipment, and the flight system during all stages of project development. The program shall address hazards in the flight hardware, associated software, ground support equipment, and support facilities.

b. Meets the system safety requirements stated in the applicable launch site safety regulation (EWRR 127-1 for the Eastern or Western Range) and the mission System Safety Implementation Plan (SSIP).

c. Meets the baseline industrial safety requirements of the institution, as well as any special contractually imposed mission unique obligations.

## 4.2. *System Description and Safety Assessment Report*

The IMPACT Phase A Report includes a detailed description of the system down to the subsystem level. This document shall serve as a baseline for the STEREO Project Safety Manager (PSM). A preliminary assessment of the IMPACT instrument's compliance with the requirements of section 4.1 follows. The PI shall continue to identify, analyze, and minimize hazards throughout the development effort. All hazards affecting personnel, launch vehicle hardware, or the spacecraft shall be identified and brought to the attention of the PSM. A synopsis of the on-going safety analysis, consistent with the maturity of the subsystem design, shall be part of each subsystem presentation at peer level and system level independent design reviews.

### 4.2.1. Preliminary Safety Assessment

The only unusual identified hazards related to the IMPACT instrument suite development and test are:

a) High Voltage: The instrument contains a number of high voltage supplies, as high as 3400V. There shall be no exposed high voltage. The supplies shall be resistively current limited on the output. The instrument can be damaged by inadvertent operation of the supplies in air. This risk is mitigated by the use of red tag disable plugs and/or green tag enable plugs, multiple series commanding interlocks, plus appropriate hazardous procedure interlocks.

b) Radiation Sources: Low level radiation sources shall be used during the calibration and test of the instruments. These sources do not fly with the instrument, but will be used during instrument and spacecraft functional tests. These sources will be handled by qualified personnel using appropriate handling procedures.

c) Non-Explosive Actuators (NEA): The instruments shall contain in-flight deployable covers using non-explosive actuators. The IMPACT boom deployment is also planned to use NEAs.  None of these actuations are expected to present a personnel hazard. Enable or disable plugs will be used to prevent unintended actuation that might expose a detector to contamination or damage the boom by deployment in 1G.

### 4.3. ***Procedure Approval***

The PI shall submit, in accordance with the contract schedule, all ground operations procedures to be used at GSFC facilities, other integration facility, or the launch site.  All hazardous operations as well as the procedures to control them shall be identified and highlighted.  All launch site procedures shall comply with the applicable launch site safety regulation.

### 4.4. ***Safety Noncompliance Requests***

When a specific safety requirement cannot be met, the PI shall submit to the PSM an associated safety noncompliance request that identifies the hazard and shows the rationale for approval of a noncompliance, as defined in the applicable launch site safety regulation.

### 4.5. ***Support for Safety Working Group Meetings***

The PI shall provide technical support to the STEREO Project Safety Manager for safety working group meetings, when necessary.

### 4.6. ***Safety Data Package, Launch Site Safety Plan, and Orbital Debris Assesment***

The spacecraft contractor shall develop these documents.  The PI shall provide input as required concerning the IMPACT instrument suite and its related ground activities that impact safety.

# 5. EEE PARTS REQUIREMENTS

## 5.1. *General Requirements*

UCB will conduct a parts control program covering the selection, procurement, and acceptance of EEE parts used on the STEREO IMPACT Instrument Suite.

The UCB Project Manager is responsible for implementation of the parts control program. Parts selection and screening plans will be done by various engineers working on the project, with final approval by the PM. Parts testing, when required, will be performed by engineers assigned to the project, and/or outside vendors.

Note that non-NASA funded institutions providing hardware to the IMPACT instrument suite will use the parts control program mandated by their funding institution. It is assumed that the parts quality level shall be similar to that imposed in this section on the NASA-funded institutions. At a minimum, sections 5.2.1 and 5.5 shall apply to all flight hardware.

## 5.2. *Parts Selection*

Parts will be selected and processed in accordance with GSFC Specification GSFC-311-INST-001 for Grade 2 quality level. Parts will be preferably selected from the following sources:

a) Parts listed in the GSFC Preferred Parts List (PPL), or the NASA Standard Electrical, Electronic, and Electromechanical (EEE) Parts List (NSPL), MIL-STD-975. Where differences in requirements exist between the PPL and the NSPL, the PPL should take precedence. Parts should be procured in accordance with the appropriate specification designated for that part.

b) MIL-M-38510, Class B or better microcircuits procured from a Qualified Products List (QPL) supplier.

c) MIL-I-38535, Class Q or better microcircuits procured from a Qualified Manufacturers' List (QML) supplier.

d) MIL-H-38534, Class H or better hybrid microcircuits procured from a Qualified Manufacturers' List (QML) supplier.

e) Standard Military Drawing (SMD) microcircuits procured from an authorized supplier as listed in the SMD.

f) Microcircuits compliant with paragraph 1.2.1 of MIL-STD-883 and procured from manufacturers having QPL or QML status for parts of the same technology. Parts procured from manufacturers without QPL or QML status should be procured with lot specific or generic Group C Quality Conformance Inspection (QCI) data within one year of the lot date code of the parts being procured. MIL-STD-883 compliant microcircuits should be subjected to PIND testing in accordance with section 5.5.

g) Manufacturers' in-house high reliability processed parts provided all screening tests listed in Appendix C of the PPL have been satisfied. The high reliability process flow should be that formally documented by the manufacturer in cases where changes would require a revision to the flow documentation. Tests not included in the manufacturer's high reliability flow must be performed by the manufacturer, an independent test facility, or by the developer. Parts procured in this section should be procured with lot specific or generic Group C Quality Conformance Inspection (QCI) data within one year of the lot date code of the parts being procured. If not included in the manufacturer's high reliability test flow, the parts should be subjected to PIND testing.

h) MIL-S-19500, JANTX, JANTXV and JANS semiconductors procured from a QPL listed supplier. It is preferred that semiconductors be procured to JANTXV level or better. Any semiconductor that has an internal cavity should be subjected to PIND.

i) Established Reliability (ER) passive components procured from a QPL listed supplier for the appropriate military specification. Only ER parts within the minimum and maximum value ranges specified in the PPL should be considered acceptable.

j) Parts procured to a GSFC S-311 specification from a GSFC approved source.

### 5.2.1. EEE Parts Identification List

A master parts list of all parts used in the IMPACT instrument suite flight hardware will be maintained by each IMPACT institution providing such hardware. The list shall be submitted to Project for approval prior to their application. This list will include, as applicable:

1) Generic part type
2) Control specification
3) Part number
4) Manufacturer
5) Lot # and/or lot date code
6) Where used
7) Total quantity used
8) Project Approval Status

An as-built parts list shall also be maintained, typically in the form of as-built PWB loading documentation.

## 5.3. *Other Parts*

Other parts, not on any of the documents listed in section 5.2, will be purchased or screened in accordance with GSFC Specification GSFC-311-INST-001 for Grade 2 quality level. The IMPACT Project Manager shall review and approve use of such parts and their application, procurement and screening plans.

### 5.3.1. Magnetic Devices

Transformers and inductors will be manufactured at UCB using magnetic components purchased from Magnetic, Inc. and Phillips, to commercial specifications, and MWS Heavy Armored Polythermaleze wire (HAPT), also purchased to commercial specifications. Parts and wire will be carefully visually inspected before and after winding. Units may be potted using approved materials at UCB. Correct operation of the completed units will be verified by electrical tests and measurements using the flight circuit boards or in special test beds.

Caltech magnetics shall be manufactured by John Gilbert, whose facility was source-inspected for ACE by JPL magnetic specialists.

## 5.4. *Derating*

All flight parts will be derated to the levels of PPL, Appendix B.

## 5.5. *Radiation Tolerance*

All EEE parts shall be selected to meet their application design requirements in the predicted radiation environment, including TID and SEE.

Parts shall have a TID tolerance of 8 Krads or more, based on manufacturers data sheet, demonstrated technology hardness, or lot testing. Shielding or special packaging may be used to achieve the desired tolerance. 8 Krads assumes 75mils aluminum shielding or equivalent (a dose vs. depth curve will be provided in the APL Environmental Specifications document, 7381-9003)

Parts shall be SEL-immune to a LET of >80 MeV-cm$^2$/mg, or else shall be protected against damage by a protection circuit. Parts that may affect critical functions that could damage the instrument shall be SEU-immune, or else shall use a Triple-Modular-Redundancy scheme to avoid any single SEU causing a failure. Parts shall meet these criteria based on manufacturers data sheet, demonstrated technology hardness, or lot testing.

## 5.6. *Alerts*

The instrument team will respond to GIDEP Alters forwarded by Project, and determine if any flight hardware or parts inventory is affected.

## 5.7. *Parts Age Control*

Integrated Circuits and Semiconductors that have a lot date code or screening record older than 7 years at the time of installation into PWBs shall first be rescreened by a visual inspection and appropriate burn-in and electrical functional tests.

# 6. MATERIALS AND PROCESSES CONTROL REQUIREMENTS

## 6.1. ***Selection Requirements***

### 6.1.1. Conventional Applications

Selection of materials will be based upon past experience, available data or current tests.

### 6.1.2. Nonconventional Applications

Use of any material that lacks aerospace experience is considered a nonconventional application. The material will be verified for the application based upon similarity, analysis, test, inspection, existing data or a combination of these methods. UCB will define the level of this verification and all information will be available for review.

### 6.1.3. Special Problem Areas

UCB will give special attention to problem areas such as radiation effects, stress-corrosion cracking, galvanic corrosion, hydrogen embrittlement, lubrication, contamination of cooled detectors, weld heat-effected zones and composite materials. No high strength fasteners or pressurized systems will be used.

### 6.1.4. Inorganic and Metallic Materials

Materials will be selected according to MSFC-SPEC-522B to control stress-corrosion cracking. Table I materials will be used to the maximum extent possible.

### 6.1.5. Non-metallic Materials

Materials will be noncombustible or self-extinguishing as much as possible. The outgassing properties of organic materials will be considered in their selection. When tested to JSC/SPR-0022A, compliant materials will have less than 1 percent total mass loss and less and 0.1 percent collected volatile condensable mass.

Solithane conformal coat materials shall be avoided, with Uralane being preferred.

### 6.1.6. Consideration in Process Selection

Manufacturing processes will be selected so as to minimize changes to the material's properties.

### 6.1.7. Shelf Life Controlled Items

Polymeric materials with an uncured limited shelf life will be identified with manufacturing data and storage conditions. Regular purchases of limited shelf life materials will be planned to assure that current date code materials are always available. Out of date materials will not be used on flight hardware.

Any other limited life material will be identified in the Limited Life Items list discussed in section 7.4.

#### 6.1.8. Magnetics Compatibility

Materials shall be selected non-magnetic wherever possible. Use of any magnetic materials shall be reviewed with the Magnetometer Co-Investigator to determine acceptability of use.

### 6.2. ***Documentation***

Documentation for materials and processes control will include:

a. Engineering Drawings for materials application
b. Materials List

The material list will be available to the Project.

# 7. DESIGN ASSURANCE AND RELIABILITY

## 7.1. *Requirements*

The IMPACT instrument suite and associated test equipment will be designed to:

a. Function properly during the mission lifetime,
b. Minimize or eliminate human-induced failures,
c. Permit ease of assembly, test, fault-isolation, repair, and maintenance without compromising performance, reliability, or safety aspects.

## 7.2. *Implementation*

The Project Manager shall ensure that system-level design and trade studies include reliability considerations. Areas where significant improvement in reliability can be achieved at the cost of increased resource requirements shall be passed on to Project. At the subsystem level, lead subsystem engineers will be responsible for reliability issues concerning their subsystem, and shall bring to the attention of the Project Manager any reliability concerns outside the scope of their allocated resources.

## 7.3. *Failure Modes and Effects Analysis*

A formal FMEA shall be performed at the spacecraft interface level to identify failures that can propagate beyond the instrument. A less formal analysis shall be performed by the Project Manager, together with subsystem engineers, as part of the design process to identify likely failure modes and mitigation schemes.

The IMPACT team shall also provide design data to Project as required to aid in the development of Reliability Assessments such as RBDs, PRAs, and FTAs.

## 7.4. *Limited Life Items*

Limited life items shall be identified and avoided when possible. The Project Manager shall compile a list of limited life items with input by the subsystem engineers. Limited life items include all hardware that is subject to degradation due to age, operating time, or cycles, such that its expected useful life is less than twice the required life, when fabrication, test, storage, and mission operation are combined. The Project Manager shall maintain a record of total operating times for these items.

# 8. QUALITY ASSURANCE REQUIREMENTS

## 8.1. *Support of Design Reviews*

QA issues and the status of the QA program will be addressed in the reviews identified in section 2.3.

## 8.2. *Document Change Control*

High level and interface documents that specify the configuration of the mission flight hardware will be controlled via a system of drawing names and/or numbers and revision letters at the system level. A revision letter assigned to each document will be incremented each time a change is made. Revision letter changes will occur only after appropriate review of the proposed document change by affected parties. If a document change requires that changes be made to existing parts, the change will be verified prior to final disposition of the document change.

Lower level design documentation change control shall be maintained by the responsible engineer in such a way that the as-built design is fully and unambiguously documented.

## 8.3. *Identification and Traceability*

Part numbers will be provided on each sub-assembly or PWB. If sub-assemblies or assemblies are not unique, serial numbers will be used to identify them.

Mechanical parts will be serialized when they are not fully interchangeable. Significant sub-assemblies (such as a sensor assembly) will be serialized for traceability.

Records will be maintained to support a trace of any non-interchangeable part or material to the board or unit in which it was placed. Parts from a given manufacturer with the same lot-date-code and screening history are considered to be interchangeable. Similarly, any board or unit will be traceable backwards to the parts or materials from which it was built. Thus, if an ALERT were to identify a problem part, IMPACT could determine all places where the part exists in the instrument.

## 8.4. *Procurement Controls*

The following procurement controls shall be imposed on all flight unit parts and materials purchases.

### 8.4.1. Purchased Raw Materials

Purchase orders for raw materials will include a requirement for the results of physical and chemical tests, or a certificate of compliance. Exceptions shall be approved by the Project Manager based on evidence of the acceptability of the material for the intended use.

Suppliers of materials will be requested to make acceptance test results available.

### 8.4.2. Age Control and Limited-Life Products

Records will be kept on products having characteristics of degradation with use or age. Records will note date, when useful life was initiated, and date when life expires.

### 8.4.3. Inspection and Test Records

UCB will require where necessary that suppliers maintain inspection and test records. Records that are to be provided with the deliverable item will also be specified.

### 8.4.4. Purchase Order Review

All purchase orders for flight articles to verify the correctness of the purchase requirements and that all applicable QA requirements have been included.

### 8.4.5. Re-submission of Non-conforming Articles or Materials

If an article is deemed non-conforming by the contractor and returned to the supplier, the supplier will resubmit the article with evidence showing the article has been corrected, and with markings which clearly indicate that it is a "re-submitted part."

## 8.5. *Receiving Inspection*

Upon receipt, all purchased products will undergo an inspection that includes:

1) Verification that documentation meets the requirements of the Purchase Order.
2) Verification that parts marking and packaging is consistent with the requirements of the Purchase Order.
3) Verification of correct parts count.

Parts will be handled in accordance with the UCB Space Physics Research Group ESD control plan (or equivalent contractor's plan), then bagged, marked, and placed into bonded flight stores.

## 8.6. *Fabrication Control*

### 8.6.1. Manufacturing Certification Log

A Certification Log will be established for each manufactured component which will travel with the item through fabrication and inspection. Operations will be done per referenced documents, or documented directly in the log book. Torque values, part serial numbers, etc. will be noted, and all entries will be signed and dated by the operator. Entries will include results of in process testing.

### 8.6.2. Workmanship

The following NASA workmanship standards shall be used in the fabrication of the IMPACT flight hardware:

Soldering - NHB 5300.4 (3A-2)
Cable, Harness, and Wiring Interconnections - NHB 5300.4 (3G)
Crimping - NHB 5300.4 (3H)
Conformal Coating and Staking - NHB 5300.4 (3J)
Printed Wiring Board Design - NHB 5300.4 (3K)

#### 8.6.2.1 Worker Certification

All flight segment soldering, wiring, and conformal coating/staking will be by technicians certified and trained as required.

### 8.6.3. Process Control

Appropriate controls will be implemented for processes for which uniform high quality cannot be ensured by inspection alone.

## 8.7. ***ESD Control***

ESD control will be accomplished by the techniques and process controls described in the UCB Space Physics Group Electrostatic Discharge Control Plan, Revision B, dated May 1990.

## 8.8. ***Non-conformance Control***

The PI will perform non-conformance control for failures and discrepancies. (A failure is a non-conformance discovered in testing, while a discrepancy is a non-conformance discovered at other times) The PI will track non-conformances with a Non-conformance Report that includes the following information:

1) A description of the non-conformance,
2) Analyses to determine the fundamental cause and any impacts to the rest of the flight instrument,
3) Remedial action to be taken,
4) Verification of the removal of the non-conformance, and
5) Disposition of the non-conforming item.

### 8.8.1. Discrepancies

#### 8.8.1.1 Documentation.

Documentation of discrepancies will begin with receipt of procured materials or fabrication.

#### 8.8.1.2 Initial Review Dispositions.

Discrepant products will be reviewed by engineering personnel to decide if they should be (a) returned for rework, (b) scrapped, (c) returned to supplier, or (d) submitted for MRB action. Initial reviews will be documented as described above.

#### 8.8.1.3 Material Review Board.

The PI will designate an MRB to review all non-conformances or instrument-level FRB closeouts resulting in MRB action. Project shall designate a voting member of the IMPACT MRB/FRB.

The MRB will: determine dispositions, ensure remedial and preventive actions; verify implementation of all dispositions; and ensure accurate records are maintained. MRB dispositions will specify one of the following:

1) Repair: The MRB will approve repairs. Although standard repair procedures may be approved on a one-time basis, the MRB will track the number of standard repairs on a per unit basis to ensure that reliability or quality are not compromised by excessive repairs.
2) Use-as-is.
3) Waiver: To use or accept hardware at the spacecraft interfaces which does not meet contract requirements; this action will require GSFC Approval prior to implementation.

### 8.8.2. Failures

#### 8.8.2.1 Reporting

A failure report will be written for failures that affect the function of the flight segment or could compromise mission objectives. Reporting will begin with the first functional test of the fully assembled component and will continue through the flight segment. All such shall be reported to the STEREO Project within one business day, with preliminary documentation provided within five business days.

#### 8.8.2.2 Failure Review Board.

The PI shall work with the STEREO Project FRB to close out all failures.

### 8.8.3. Alert Information

The PI will support the Alert program by determining the relevance of each Alert submitted to UCB. If action is required, the MRB will determine the approach to resolving the problem.

## 8.9. ***Inspections and Tests***

UCB will plan and implement an inspection and test program that will demonstrate that applicable requirements are met. Inspection and in process testing will be completed prior to installation into the next level of assembly

Verification of soldering to NHB 5300.4 (3A-2) will be done by NASA certified personnel other than the original operator.

The component responsible engineer will review the hardware and documentation package prior to certification of readiness for the next assembly process.

The responsible engineer will perform an end-item inspection on each component. It will be verified that the configuration is as specified in the released design documentation, that workmanship standards have been met, and that test results are acceptable.

### 8.9.1. Inspection and Test Records

Inspection and test records will be included in the manufacturing certification log for each deliverable component, to show that all manufacturing operations have been performed, the objectives met, and the end item fully verified.

### 8.9.2. Printed Wiring Boards Inspections and Tests

Printed wiring boards shall conform to the requirements of Mil-P-55110, and shall be qualified by inspection and test results. PWB coupons shall be evaluated by GSFC or a GSFC approved laboratory for evaluation and approval prior to loading with flight parts.

## 8.10. *Metrology*

Verification of the accuracy of test equipment to the necessary levels during testing and calibration of the flight instrument will be done by a combination of calibration by outside vendors and cross-checking of one unit against another.

## 8.11. *Handling, Storage, Marking, Shipping, Preservation, Labeling, and Packaging*

### 8.11.1. Handling

No handling equipment is planned for the IMPACT project. In the event that a need for such equipment is identified, appropriate proof testing will be performed prior to use.

### 8.11.2. Shipping

Shipping of the flight units or components will be done with the appropriate accompanying documentation and handling instructions.

## 8.12. *Government Property Control*

UCB and its subcontractors shall be responsible for and will account for all property procured under the contract or provided by the government. The University property control system and standard government property transfer forms will be used to accomplish this.

## 8.13. *End Item Acceptance*

Prior to shipment of the IMPACT Instrument suite, the Acceptance Data Package will be assembled by the Project Manager and reviewed by Project or its designee at the Pre-ship review.

## 8.14. *Ground Support Equipment*

Mechanical and Electrical Ground Support Equipment that directly interfaces with the flight hardware shall be subject to a subset of these Quality Assurance standards, such as Metrology, Configuration Management, and Contamination Control as required. The quality level of the GSE shall be sufficient to ensure that the flight hardware connected to it is not compromised, and the operations performed with the GSE are consistent, correct, and safe.

# 9. CONTAMINATION CONTROL

The STEREO IMPACT instruments contain contamination sensitive detectors (Microchannel Plate detectors and Solid State Detectors). The detectors are sensitive to dust, water, and most aromatic hydrocarbons. Some analyzers contain high voltages (up to 3500V). In addition, some surfaces such as radiators shall be contamination sensitive.

For the detectors, rather than impose a requirement on surface contamination, we rely on proven procedures. Measuring contamination buildup is very difficult since many of these detectors are buried deep in the analyzers. The procedures used have proven to be adequate on numerous previous missions.

The detectors are stored, handled, and installed into the flight instruments in appropriately clean environments by experienced technicians using systems that have been used successfully on numerous previous instruments. Once installed into the flight hardware, the detectors are sealed behind covers with positive flow of high grade dry Nitrogen to prevent contamination. In this configuration, good housekeeping cleanliness levels are adequate to maintain the cleanliness of the exterior of the instrument. Prior to delivery to spacecraft integration, the exterior of the instrument shall be cleaned to meet the spacecraft-level cleanliness requirements. A bakeout, if required, will be included as part of the subassembly thermal vacuum tests.

Nitrogen purge shall be maintained on a near-continuous basis throughout I&T, at least up to encapsulation. Occasional outages in the Nitrogen flow can be tolerated for a few hours.

For tests that require the removal of the aperture covers, exposing the detectors, the instrument should be bagged or otherwise maintained in a class 100,000 environment or better, and Nitrogen flow should be continuous. Such exposures should be limited in duration to a few hours total. Alternatively, longer duration at a better cleanliness level can be tolerated.

The instrument shall be fabricated from low-outgassing materials as discussed in section 6 of this PAIP to minimize contamination of itself or other instruments.

Some of the solid state detectors will be cold in space, and so present an enhanced contamination problem due to condensation (especially STE). In some cases, where the detectors are exposed and cold (STE and SEPT), reclosable covers have been provided so that the detectors will not be exposed during thruster firings.

Some of the analyzers contain high voltages (up to 3500V). These supplies can only be turned on in a good vacuum to avoid arcing. This implies outgassing requirements, thermal vacuum test requirements, and possibly powering off some of the supplies for thruster firings. Normal spacecraft materials requirements plus a 24 hour outgassing interval before powering up the supplies should be sufficient.

# 10. SOFTWARE ASSURANCE

## 10.1. *General*

The Space Physics Group at the UCB Space Sciences Laboratory has had considerable experience in the development of real time processor-based systems for spaceflight use (including the first microprocessor system flown on a NASA satellite - ISEE-1) and computer-based ground support equipment. The group currently includes persons of considerable ability and experience in the software area. The group has developed approximately 25 such systems over the past 15 years, all of which have been delivered on schedule and have been completely successful.

It is our intent to use the same type of organization and development procedures and coding practices on IMPACT that has proven to be successful on past programs.

Flight Software is the instrument computer code that runs in the micro processor(s) which are a part of the flight experiment package. Only Flight Software is covered by this document. GSE software shall be developed using reasonable practices, and shall only be controlled to the extent that critical GSE used for acceptance tests at the system level shall be under configuration control starting at the beginning of system-level testing.

## 10.2. *Software Development*

IMPACT software development includes the following subsystems:

- IDPU flight processor (UCB)
- SEP common electronics flight processor(s) (Caltech/GSFC)
- Instrument Command and Display GSE software (UCB)
- Science Display GSE Software (Caltech, UCB, UNH)
- Subsystem-level test GSE software (various)
- Mission Operations Software (UCB)

Software will be by a small team of programmers (typically one per subsystem). Control is maintained by the programmer for a subsystem, who is responsible for maintaining the code and incorporating all changes at a single location throughout its lifecycle.

### 10.2.1. Responsibilities

All software is ultimately the responsibility of the IMPACT Project Manager. He or his delegate is responsible for approving the software functional requirements, and for approving any deviations to those requirements in the software implementation, and for approving the final flight software has been adequately tested and is ready to install. For the SEP software the Project manager shall delegate this responsibility to a member of the SEP team who is on-site and more knowledgeable about the SEP system.

A requirements document is developed for each software subsystem by the subsystem programmer, in close consultation with the relevant investigators and engineers. Once the requirements are approved, the programmer begins designing and then developing code.

The programmer is responsible for developing, maintaining, and testing the code, and maintaining configuration control of the code.

Software testing will start at the module level to ensure that each module performs correctly. System-level Acceptance testing of the software will ensure that the code is thoroughly tested and meets all its requirements. To the largest extent possible, testing will be performed by personnel not responsible for the development of the code.

Software documentation, such as the requirements document, may be part of a higher level document covering hardware and software, provided it is clear what part of the task is to be performed by the software.

#### 10.2.2. Development Plan

Software development shall proceed incrementally in support of the hardware development. The usual development approach consists of a series of "builds". These builds are somewhat artificial, since the software is actually developed in a smoother process of many iterations. They only serve to indicate where the software development interacts with the hardware development and test, and as a management tool to track software development progress. For example, in the case of the flight IDPU software, the planned series of builds are:

1. The first build shall exercise all hardware functions. This version shall be used in early hardware check-out.
2. The second build shall include all interface protocols and message passing, but may not include all science data processing or automated instrument control. This version is adequate for system-level testing.
3. The third build shall include all functionality, ready for flight. This version should be installed prior to the start of system acceptance tests.

Software changes shall be progressively more tightly controlled with each build (see section 10.5).

### 10.3. *Documentation*

The instrument software will be documented at a minimum by the following:

| | |
|---|---|
| Software Management Plan | Describes the flight software development plan as called out in the IMPACT contract deliverables list. |
| Software Requirements: | Describes the functional requirements on the software to a level sufficient for a programmer to implement. |
| Software Users Guide: | Describes the software at the interface level for the end user (scientists, operations personnel and ground software programmers). |
| Software History Log: | This log will include all PFRs (with dispositions), results of acceptance testing, and detailed descriptions of any modifications made by uplinked code after launch. This is the programmers log book. |

The subsystem programmer will be responsible for developing these documents and maintaining configuration control over them. This control will consist of reviewing and implementing any document changes, maintaining a revision code on all document updates, and distributing the documents for review to interested parties.

### 10.4. *Software Design Reviews*

External software design reviews shall follow the same model as the other subsystems, as called out in sections 2.3. In addition, internal design reviews shall be held as required to ensure that the software requirements are adequately understood and implemented.

### 10.5. *Configuration Management*

Configuration control on the software will be performed by the subsystem programmer, and any change requests or bug reports will be communicated to him. Version numbers will be assigned and maintained by the subsystem programmer.

Prior to the beginning of acceptance testing, when the code is complete and ready to test, additional controls will be put in place. Any failures or change requests will be made to the subsystem programmer via the Problem/Failure Report system. The subsystem programmer will verify the problem and determine the cause. If the problem can be fixed without impacting the functionality of the rest of the code and does not have a serious schedule impact, he will proceed with the fix, and distribute a new revision of the code for further tests. Any instrument S/W modifications, no matter how seemingly minor, will be verified by a complete S/W acceptance test. Problems with greater impact will be submitted to a review board consisting of at least the subsystem programmer, the Instrument Project Manager, and the PI. The subsystem programmer shall maintain a logbook of all PFRs.

When all PFRs have been dispositioned and the final version of the code has completed acceptance testing, the code will be committed to the flight PROMs and installed into the flight hardware. From this point on, all change requests must be approved by the Project Manager, and will only be considered for a serious problem that cannot be fixed by uplinking a software “patch” after launch. If a change is approved, the subsystem programmer will implement the fix and issue a new release. The new release will be submitted to a full acceptance before again committing to PROM.

Any code to be uplinked after launch will be submitted to the same level of configuration control as was levied on the final version of the flight code, including detailed acceptance testing on breadboards prior to uplinking the code. Any significant code uplink will be accompanied by a change in the code version number which is included in the instrument housekeeping, so that ground data processing software can determine what version of the software is running.

At all stages of the software development, a system of backups will be maintained to ensure that the failure of a system or media will not destroy more than 1 day's work. In addition, a backup copy will be maintained off-site, updated periodically.

# Appendix A - APPLICABLE DOCUMENTS

The following documents shall be applicable to this PAIP to the extent referenced herein.

| Document No. | Title |
|---|---|
| GEVS-SE | General Environmental Verification Specification for Small Expendables (revision : TBD) |
| MIL-STD-461C | Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference |
| MIL-STD-462 | Electromagnetic Interference Characteristics, Measurement of |
| MIL-STD-463 | Military Standard Definitions and System of Units, Electromagnetic Interference and Electromagnetic Compatibility Technology |
| MIL-STD-1574A | System Safety Program for Space and Missile Systems |
| WSMCR 127-1 | Western Space and Missile Center Range Safety Requirements |
| S-311-555 | GSFC Specification, Parts Selection Guide for the Small Explorer Program |
| MIL-STD-975 (NASA) | NASA Standard Electrical, Electronic, and Electromechanical (EEE) Parts List |
| MSFC-SPEC-522B | Design Criteria for Controlling Stress Corrosion Cracking |
| MIL-STD-6866 | Military Standard, Inspection, Liquid Penetrant, 29 November 1985 |
| None | GSFC Materials Tips for Spacecraft Applications |
| TM 82275*(GSFC Mtr. No. 755-013) | Quality Features of Spacecraft Ball Bearing Systems |
| TM 82276*(GSFC Mtr. No. 313-003) | An Evaluation of Liquid and Grease Lubricants for Spacecraft Applications |
| None | Materials Selection Guide, GSFC, June 1985 |
| N-84-26751*(NASA RP-1124) | Outgassing Data for Selecting Spacecraft Materials |
| NHB 8060.1B | Flammability, Odor, and Outgassing Requirements and Test Procedures for Materials in Environments that Support Combustion |
| MSFC-HDBK 527 JSC 09604, Rev. C | Materials Selection List for Space Hardware Systems |
| NHB 5300.4 (3A-1) | Requirements for Soldered Electrical Connections |
| NHB 5300.4 (3G) | Requirements for Interconnecting Cables, Harnesses, and Wiring |
| NHB 5300.4 (3H) | Requirements for Crimping and Wire Wrap |
| NHB 5300.4 (3I) | Requirements for Printed Wiring Boards |
| NHB 5300.4 (3J) | Requirements for Conformal Coating and Staking of Printed Wiring Boards and Electronic Assemblies |
| NHB 5300.4 (3K) | Design Requirements for Rigid Printed Wiring Boards and Assemblies |
| DOD-HDBK-263 | Electrostatic Discharge Handbook for Protection of Electrical and Electronic Parts |
| DOD-STD-1686 | Electrostatic Discharge Program for Protection of Electrical and Electronic Parts |
| MIL-P-55110 | General Specification for Printed Wiring Boards |
| MIL-STD-45662 | Calibration System Requirements |
| GSFC PPL-21 Notice 1 | Preferred parts list |

# Appendix B - Foreign Co-I Performance Assurance Plans

### B.1 Product Assurance for SEPT Development at ESTEC

Performance insurance requirements for the hardware produced by Space Science Department of ESA will follow the ESA standard procedures and rules published in Space Product Assurance Policy and Principle, ECSS-Q-00A, 19 April 1996 and associated documents listed in the table below.

Product Assurance within the Space Science Department of ESA is under the control of the Space Science Department Product Assurance Manager, Mr. Bengt Johlander. He will be responsible for all aspects of PA including parts selection, assembly, qualification etc, during manufacturing of the SEPT electronics.

Mr Johlander is head of the Flight Instrument Support Group of the Space Science Department of ESA, which has in the past been responsible for design and manufacture and PA/QA of SSD instruments on board ESRO-1, GEOS, HEOS, MAGIK, VIKING, ISEE-3 VEGA, GRO, PHOBOS, TETHER, ULYSSES, SOVA, WIND, Equator-S, SOHO, CASSINI-Huygens and CLUSTER II.

Space Science Department of ESA will do electronics for SEPT, University of Kiel will do the mechanics. Product assurance will follow this approach. After integration of SEPT into SEP and IMPACT we will leave PA/QA activities in the hands of SEP and IMPACT team.

**Table 1: Space product assurance policy and associated documents**

| document name | document number, Iss./Rev. |
|---|---|
| Space Product Assurance, Policy and Principles | ECSS-Q-00A, 19 April 1996 |
| Space Product Assurance, Quality Assurance | ECSS-Q-20A, 19 April 1996 |
| Space Product Assurance, Dependability | ECSS-Q-30A, 19 April 1996 |
| Space Product Assurance, EEE Components | ECSS-Q-60A, 19 April 1996 |
| Space Product Assurance, Materials, Mechanical Parts and Processes | ECSS-Q-70A, 19 April 1996 |
| Guide to applying the ESA software engineering standards to small software projects | BSSC(96)2 iss. 1, May 1996 |
| Derating Requirements | ESA-PSS-01-301 |

**List of foreseen documentation**

Basically the documentation will follow ESA standard as stipulated in Space Product Assurance Policy and Principle, ECSS-Q-00A, 19 April 19. The list of foreseen documents is given in the table below.

| |
|---|
| SEPT requirements and specification document |
| SEPT user document |
| SEPT EGSE documentation and user manual |
| SEPT product assurance requirements |
| SEPT verification test procedures |
| SEPT verification test report |
| SEPT parts, material and process list |

| |
|---|
| SEPT loose part list (if applicable) |
| SEPT open items list |
| SEPT interface control drawings (ICD) |
| SEPT technical drawings |
| SEPT manufacturing record (only for EM, FM and FS) |
| SEPT handling log |
| SEPT non conformance report list |
| SEPT request for waiver list |

### *B.2 Performance Assurance for SEPT Development at Keil*

# Performance Assurance Implementation Plan (PAIP)

# for the STEREO IMPACT SEPT Sensors

**1.** This Appendix to the STEREO / IMPACT Product Assurance Plan shall cover the product assurance procedures and requirements for the SEPT sensor heads provided by the University of Kiel, Germany. The SEPT sensor heads will be integrated with the SEPT electronics provided by the Space Science Department of ESA, which will provide a separate product assurance plan statement.

**2. Heritage**

The SEPT sensors are based on sensors, instruments, and experiments built and managed by the University of Kiel Team for the international space science project ULYSSES (COSPIN / KET), SOHO (COSTEP Experiment), and CHANDRA (Radiation Monitor). No major problems were encountered during these projects in complying with the product assurance requirements both from the project offices and from the experiment management.

**3. Product assurance statement from the University of Kiel IMPACT-SEPT Team.**

The University of Kiel STEREO / IMPACT / SEPT Team will comply with all applicable requirements and procedures described in the STEREO / IMPACT Product Assurance Plan (PAIP), July 20, 2000. Procedures developed in previous projects will be used or updated to assure safety, quality, and reliability of parts, components, and items. The required documentation will be provided to support design, fabrication, and test control, reviews and acceptance/qualification. This will specifically include parts and material lists, thermal and structural analysis, contamination control, and configuration management.

**4. Product Assurance Requirements imposed by the German Funding Agency DLR**

No specific product assurance requirements are so far imposed by the German Funding Agency DLR nor have been imposed in previous projects. The application for funding sent to DLR provides for compliance with the product assurance implementation plan for the STEREO / IMPACT instrument suite The compliance with the above plan, however, is based upon the financial support and conditions imposed by DLR once the grants for STEREO / IMPACT / SEPT are provided.

### *B.3 Performance Assurance for SWEA Development at CESR*

## PRELIMINARY PERFORMANCE ASSURANCE FOR SWEA

For the STEREO IMPACT INSTRUMENT SUITE, which is under the responsibility of the P.I. J. Luhman from Space Science Laboratory at U.C.B., the Centre d'Etude Spatiale des Rayonnements (CESR) is in charge of the development of the Solar Wind Electron Analyzer (SWEA).

This development is funded by the French space agency – CENTRE NATIONAL D'ETUDES SPATIALES (CNES) with the request to pursue with the advises explained in the document:

### Guide pour les Projets Scientifiques

*Ref : DTS/AQ/QP 98-083*
*Edited by the Product Assurance Delegation of CNES*
(see Table of Contents in annex 1).

CESR will follow these guidelines and in particular for Product Assurance.

Moreover, development of SWEA at CESR will be made following the Product Assurance Plan which was prepared to realize sub-systems for the 3D-PLASMA instrument – in cooperation with SSL – for the WIND project:

### Performance Assurance Implementation Plan

*High Voltages and Digital Electronics*
*Ref : CESR 88-1252, Iss : 1, Rev : 0.*

For EEE components, Quality Level 3 – as defined by CNES for scientific projects – will be used. A higher grade part will be used if there is no cost penalty or no grade 3 part is available.

*Note:* This Quality Level 3 is equivalent to the Quality Level 3 defined in NASA document 311-INST-001, Rev. A, Instructions for EEE Parts Selection, Screening and Qualification.

CESR intends to be in compliance with the principal features of the PAIP for the STEREO IMPACT INSTRUMENT SUITE, and will provide documentation listed in annex 2.

| ***Lead Co-I*** | ***Project Manager*** |
|---|---|
| J.A. SAUVAUD | F. COTIN |

# ANNEX 1

## GUIDE POUR LES PROJETS SCIENTIFIQUES

*(CNES – Ref : DTS/AQ/QP 98-083)*

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# ANNEX 2

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