PERFORMANCE ASSURANCE IMPLEMENTATION PLAN

FOR THE HESSI PROJECT

Contract Number: NAS5-98033

UCB Approvals: ________________________________
Dr. Robert Lin, HESSI Principal Investigator

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Peter R Harvey, HESSI Project Manager

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Ron Jackson, HESSI Performance Assurance

GSFC Approvals: ________________________________
GSFC Mission Manager

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1. GENERAL

1.1 Basis and Scope of the Plan

The following Performance Assurance Implementation Plan (PAIP) has been prepared in response to the requirements set forth in the HSI_PA_000.DOC document henceforth referred to as the PAR.

HESSI is the first Small Explorer program performed in the PI mode; i.e. all components of the spacecraft and ground systems provided by the Principal Investigator.

The HESSI project is an international effort of several universities, industrial partners, and NASA. The Principal Investigator is Professor R. P. Lin at the University of California at Berkeley (UCB). The spectrometer part of the instrument will be built at UCB, the imaging telescope at the Paul Scherrer Institute (PSI) in Zurich, Switzerland, and the spacecraft at Spectrum Astro Inc., of Phoenix, Arizona. NASA's Goddard Space Flight Center (GSFC) is supporting both the spectrometer and imaging telescope and has overall responsibility for the analysis software and data archiving at its Solar Data Analysis Center. HESSI will be controlled in orbit from UCB using its on-site antenna.

Other collaborating U.S. institutions include National Oceanic and Atmospheric Administration (NOAA), Lawrence Berkeley National Laboratory, California Institute of Technology, Jet Propulsion Laboratory, Montana State University, University of California at San Diego, and the University of Alabama at Huntsville. International contributors include the Institute of Astronomy ETHZ in Switzerland, Delft university of Technology in the Netherlands, University of Glasgow, Scotland, National Astronomical Observatory, Japan, and Observatoire de Paris-Meudon, France.

1.2 General Requirements

The PI for the HESSI Mission 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 and spare flight equipment. This plan will be used by the PI and all subcontractors which fabricate or test such equipment. This plan does not apply to ground support, mission operation, data analysis equipment or software. The spacecraft bus product assurance is documented in Spectrum Astro's "High Energy Solar Spectroscopic Imager (HESSI) Program Product Assurance Plan", document # 1110-EP-Q09929.

This document addresses each of the six sections of the PAR.

1.3 Use of Previously Designed, Fabricated, or Flown Hardware

No previously fabricated or flown hardware will be used for this instrument. Any previously designed section of the hardware will be subject to the PA requirements of this PAIP.

1.4 Performance Assurance Status Report

The Project Manager will prepare reports as required covering performance assurance activities, any outstanding deficiencies which could adversely affect the end-item performance, and the intended corrective actions to be taken. Reporting will be part of the Project Status Report delivered to the technical officer and will cover:

- Significant assurance problems, including a summary of any inspections and tests that failed, and sub-contractors' PA problems.
- Unresolved hazards.
- Summary of Alerts and their dispositions.

1.5 Flow-Down of PA Requirements

The PI will insure that all vendors and subcontractors which supply hardware for the HESSI Mission will meet applicable QA requirements.

The PI and possibly instrument fabrication subcontractors will be procuring parts and materials for the flight instrument. Personnel responsible for performance assurance will assist in the selection of procurement sources. All available information such as performance history, receiving inspections and test results (e.g., ALERT information), will be used to assess the capability of each potential procurement source.

1.6 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.

1.7 Glossary (Appendix B)

Appendix B lists definitions that are needed for a common understanding of terms as applied in this document.

1.8 Surveillance of the Principal Investigator

GSFC has delegated authority to Office of Naval Research in order to perform surveillance and /or inspection of UCB activities and to provide independent advice to the PI regarding the PA activities if required.

The PI will provide such representatives with any documents and records outlined in the PAIP, equipment and working space at UCB required by and consistent with the overview activities. Since work space at the Space Sciences Laboratory is extremely limited, UCB will need significant advance notice of any overview activity which requires working space. Other inspections may be unannounced.

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, software and operations.

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 Confirmation Review (CR) which will cover programmatics (schedule and cost) based upon the PDR results.
c. A Critical Design Review (CDR) which occurs before the bulk of the flight fabrication begins. The topics include test plans for the flight segment and results of development tests.
d. Pre-Environmental Review (PER) which occurs after the spacecraft is complete and before the full environmental tests are performed.
e. A Pre-Shipment Review (PSR) which occurs prior to shipping the spacecraft to be integrated with the launch vehicle. Its purpose is to evaluate the flight hardware performance during testing and determine the readiness of the instrument for integration with the spacecraft.
f. A Flight Readiness Review (FRR) which occurs prior to launch to determine if the spacecraft is ready to launch, ground segment is ready to contact the spacecraft, and the tracking systems are ready to return orbit information.

2.4 System Safety

System safety status will be discussed at each review.

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, analysis, 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.

3.1.1 System Safety Considerations

The Project Manager will coordinate the efforts of the verification program with those required by the safety program.

3.2 Documentation Requirements

The HESSI Systems Engineer will be responsible for managing the collection and distribution of verification documentation. This documentation will include a Verification Plan Specification, Verification Procedures, and Verification Reports.

3.2.1 Verification Plan Specification

The Verification Plan Specification will detail an array of tests, analyses and inspections which demonstrate flight unit compliance with (1) Electrical Functional requirements, (2) Structural and Mechanical requirements, (3) Vacuum and Thermal requirements, (4) Electromagnetic Compatibility and (5) End-to-End Compatibility requirements.

3.2.2 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, and will be available for inspection by appropriate GSFC personnel on request.

3.2.3 Verification Test Report

A formal VTR sheet 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. This report shall be part of the HESSI Acceptance Data Package (ADP).

3.3 Functional Test Requirements

3.3.1 Electrical Interface Tests

Electrical interface tests will be performed as each board of the flight unit is ready to be integrated to the rest of the system. High and low impedance lines (inputs and outputs) will be checked for proper connections. Open collector or tri-stated busses on interfaces will require careful checks to be sure that multiple devices do not contend for the buss, etc. Such problems do not show up until mated with other units.

Particular attention will be focused on the power lines to the boards and the harnessing in general. Major problems can be caused by errors in these areas. Where practical, the boards may be designed to have protection against errant voltage application, buss contention and so forth. Where this approach is not feasible, external power checking (current limiting, etc.) may be used.

Documentation of such tests will be done in lab notebook format.

3.3.2 Post Integration Functional Tests

Following integration, the operation of all elements will be verified by appropriate functional testing. Appropriate stimulation and particle sources will be used for these tests. Documentation will be in laboratory notebooks which will be available for GSFC inspection.

3.4 Structural and Mechanical Requirements

3.4.1 General Requirements

Compliance with mechanical and structural requirement will be demonstrated by a series of tests and analyses. Factors of safety, interface compatibility, workmanship, and compliance with launch vehicle and range safety requirements will be demonstrated.

3.4.2 Requirements Summary

Structural and mechanical tests will be performed as specified in Table 3-1.

3.5 Electromagnetic Compatibility (EMC) Requirements

Naturally, the most valuable and definitive EMC testing is that which is done at the S/C level of assembly. However, to increase confidence that the design is free of EMC problems, the testing specified in the verification matrix will be done as early as practical in the payload development program..

3.6 Vacuum and Thermal Requirements

3.6.1 General Requirements

A program of thermal vacuum testing will be performed to demonstrate that the spacecraft (1) will perform satisfactorily in space, and (2) can withstand the thermal and humidity environments expected in transportation and storage.

3.6.2 Summary of Requirements

Testing and analysis will be performed by UCB and PSI on all flight instrument components. Spectrum Astro will perform thermal tests on all flight spacecraft bus components prior to bus integration and delivery to UCB. After the instruments are integrated to the spacecraft , the spacecraft will be tested in thermal vacuum.

3.6.3 Detailed Requirements

Components which undergo thermal vacuum testing will perform a functional test at both the high and low temperature extremes. Temperature extremes will be 10 degrees centigrade below the predicted minimum operating temperature and 10 degrees above the predicted maximum operating temperature. The total number of cycles for each component are included in the Verification matrix.

3.7 End-to-End Testing

The HESSI Mission end to end testing will be performed at UCB using the spacecraft, ground station, MOC and SOC. This testing will be documented on the HESSI web site.

3.8 SYSTEM SAFETY REQUIREMENTS

UCB will plan and implement a system safety program that meets the requirements outlined in the PAR. This will include the development and submission of System Description and Safety Assessment Reports, Safety Noncompliance Requests and the preparation of a Safety Data Package.

A safety plan which addresses these issues will be developed in cooperation with GSFC.

4. EEE PARTS REQUIREMENTS

4.1 General Requirements

UCB will conduct a parts control program covering the selection, procurement, and acceptance of EEE parts used on the HESSI Mission.

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.

4.2 Parts Selection

Parts will be preferably selected from the following sources:

1) GSFC Specification GSFC-311-INST-001
2) GSFC PPL-22
3) Mil-STD-975 H (except magnetic devices)
4) Micro circuits procured to Mil-M-38510 and Mil-STD-883C
5) JANTXV Semiconductors procured to Mil-S-19500
6) Hybrid micro circuits procured to Mil-H-38534.

Parts will, for the most part, be used without additional screening beyond that included in the procurement specification. Specifications in the PPL and Mil-STD-975 may be relaxed in some cases to the level of Mil-STD-883C, to make procurements consistent with the SMEX philosophy of the acceptance of limited risk.

4.3 Additional Parts

4.3.1 Magnetic Devices

Transformers and inductors will be manufactured at UCB using magnetic components purchased from Magnetic, Inc. and Ferroxcube, to commercial specifications, and Beldon Heavy Armored Polythermaleze wire, also purchased to commercial specifications. Parts and wire will be carefully visually inspected before and after winding. Units will 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.

4.3.2 Other Parts

Other parts, not on any of the documents listed in section 5.2 will be purchased to screening requirements consistent with at least the level of Mil-STD-883C. Part screening documents will be available for GSFC inspection on request.

4.4 Derating

All parts used on the HESSI payload will be derated to the levels of PPL, Appendix B, or Mil-STD-975 H, Appendix A.

4.5 EEE Parts Identification List

A master parts list of all parts used in the HESSI science payload will be maintained. This list will include, as applicable:

1) Generic part type

2) Control specification
3) Part number
4) Manufacturer
5) Lot # and date code
6) Where used
7) Total quantity used

The list will be available starting at PDR and updated as needed until instrument delivery.

Review of the parts list against GIDEP/NASA alerts will be performed as such alerts are received from GSFC.

4.6 Quality Assurance

All parts will be visually inspected upon receipt at UCB and placed in bonded stores. All parts will functionally verified by a careful functional check following their installation at the circuit card level. Parts which cannot be verified in circuit may undergo product verification testing or verification of manufacturer's test data by QA at UCB prior to board assembly.

Destructive Physical Analysis may be used on selected parts lots if needed to demonstrate lot integrity.

4.7 Radiation Tolerance

A combination of intrinsic part hardness and shielding will be used to meet the radiation requirement for the HESSI Mission. Maximum use will be made of radiation tolerant design techniques, allowing comfortable timing margins, and providing substantial margin in the power converters.

The HESSI baseline is to use parts with a total dose radiation tolerance of 20 K rads or more. The single-event latchup potential for each device will be evaluated and circuitry provided as necessary to mitigate the SEL concerns.

5. MATERIALS AND PROCESSES CONTROL REQUIREMENTS

5.1 General Requirements

The PI will implement a comprehensive program for materials and processes control.

5.2 Selection Requirements

5.2.1 Conventional Applications

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

5.2.2 Nonconventional Applications

Use of any material which 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.

5.2.3 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.

5.2.4 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.

5.2.5 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.

5.2.6 Consideration in Process Selection

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

5.2.7 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 be removed from bonded stores and discarded.

5.3 Documentation

Documentation for materials and processes control will include:

a. Engineering Drawings for materials application
b. Inorganic Materials List (GSFC Form 18-59A or equivalent)
c. Polymeric Materials List (GSFC Form 18-59B or equivalent)

Materials lists will be available to the GSFC, formatted in accordance with Appendix C.

6. DESIGN ASSURANCE AND RELIABILITY REQUIREMENTS

6.1 General Requirements

The PI will implement a design assurance program consistent as described below.

6.2 Design Assurance

6.2.1 Requirements

The HESSI instrument 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.

6.2.2 Principal Investigator Support for Design Assurance

The Project Manager will ensure that:

1. Quality, reliability, safety and maintainability considerations are factored into the design,
2. The instrument can be inspected and tested,
3. The instrument can be produced,
4. The detailed design conforms to the requirements,
5. The performance, safety and interface specifications are reflected in inspection and test documentation,
6. Operations in which high quality cannot be verified by inspection alone are identified and methods are established to ensure instrument integrity.

6.2.3 Specifications, Drawings and Test Procedures

6.2.3.1 Design Specifications

UCB will develop an electrical design specification in block diagram form for the HESSI Mission system. Interface protocols between major blocks will be indicated on the diagram. A master mechanical layout will also be developed and maintained which will define mechanical form and fit including mounting hole patterns and connector locations for each deliverable component.

6.2.3.2 Specification, Drawing and Test Procedure Reviews.

Instrument box-level and board-level design specifications will be written by, or checked by, the SE. Spacecraft box-level specifications will be developed by Spectrum Astro and reviewed by the SE.

Instrument box-level and board-level drawings will be reviewed by the SE periodically throughout the development, prior to release and following any changes occurring after release. Spacecraft box-level and board-level drawings will be controlled internally at Spectrum Astro and will be available to the SE at any time for review. However, change notification is not provided for changes which do not affect the functional specification or the interfaces.

Test procedures used at the spacecraft level will be reviewed by the SE in order to match the test results to the requirements and specifications they are intended to verify.

6.3 Reliability Analyses

6.3.1 Failure Mode Effects and Criticality Analysis

To assist in the payload system design, a FMECA will be performed early in the design process as soon as the system electrical specification begins to firm up. Problem areas identified in the analysis will result in corrective action being taken by modifying the system design. The FMECA process will be performed iteratively, as required, until a satisfactory design is obtained.

6.3.2 Parts and Device Stress Analysis

Stress analysis of the digital and analog electronics will be performed by the digital and analog designers, respectively, as part of the design process.

Analysis will consider environmental stresses and reference the derating guidelines of MIL-STD-975 and/or PPL. It will be performed using the worst case stresses which can result from the specified performance requirements. The analysis will be updated as the design changes.

7. QUALITY ASSURANCE REQUIREMENTS

7.1 General Requirements

The PI will establish and maintain a quality assurance program which is detailed below.

7.2 Support of Design Reviews

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

7.3 Document Change Control

Documents which specify the configuration of the mission flight hardware will be controlled via a system of drawing numbers and revision letters. Standard techniques of materials call-out from assembly drawings to lower level assemblies and piece-part drawings will define the entire payload. Master copies of all documents will be stored in a central location. A revision letter assigned to each document will be incremented each time a change is made. Revision letter changes will be tracked using an Electronic Engineering Change Order (EECO) form, and will occur only after appropriate review of the proposed document change.

The impact of a change will be specified on the EECO form. If the EECO requires that changes be made to existing parts, the change will be verified prior to final approval of the EECO. Parts will be marked or tagged with drawing numbers and revision level, and the correct revision level verified at assembly into the next higher level.

A master drawing list will track the revision level of all parts in the Mission. The master parts list, when properly updated, will become the as-built configuration list.

7.4 Identification and Traceability

UCB will maintain a product identification and tracking system for the HESSI Mission. 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 a given lot-date-code 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, UCB could determine all places where the part exists in the instrument.

7.5 Procurement Controls

UCB will include the following procurement controls on all flight unit parts and materials purchases.

7.5.1 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.

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

7.5.2 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.

7.5.3 Inspection and Test Records

…… 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.

7.5.4 Purchase Order Review

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

7.5.5 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."

7.6 Receiving Inspection

UCB will maintain a person or persons who perform receiving inspection for the HESSI Project. Upon receipt at UCB, all purchased products will undergo an inspection which 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 Space Physics Research Group ESD control plan, then bagged, marked, and placed into bonded flight stores.

7.7 Fabrication Control

7.7.1 Fabrication and Assembly Flow Plan

A fabrication and assembly flow plan will be developed which outlines the manufacturing, assembly, inspection, and test steps which are required to produce the HESSI Mission. This plan will be in engineering drawing format on one or more D-size sheets. It will be controlled as a standard drawing. A copy will be submitted to GSFC for review and comment 30 days prior to the PDR and again 30 days prior to the CDR.

7.7.2 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.

7.7.3 Worker Certification

All flight segment soldering and wiring will be done in accordance with NHB 5300.4 sections 3A-2, 3G, 3H, 3I, and 3J, by technicians certified and trained as required.

7.7.4 Process Control

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

7.8 ESD Control

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

7.9 Non-conformance Control

UCB 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.) UCB will track non-conformances with a Non-conformance Report which 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.

7.9.1 Discrepancies

7.9.1.1 Documentation.

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

7.9.1.2 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.

7.9.1.3 Material Review Board.

The MRB will review all non-conformances or instrument-level FRB closeouts resulting in MRB action.

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.

GSFC reserves the right to reverse the decision of MRB on repairs at the interface level.

7.9.2 Failures

7.9.2.1 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.

UCB will provide the GSFC with copies of all failure reports.

A master file of the reports and supporting tests or analyses will be maintained at UCB for Project information.

7.9.2.2 Failure Review Board.

The FRB will designate remedial action to be taken. Where an affected item is discrepant, the FRB will closeout the failure by referring it to the MRB. The FRB will be performed by the following groups: Engineering, Systems Engineering and Quality Engineering.

The FRB will investigate failures beginning with the component level functional tests and documented at UCB. Failures at the instrument level functional tests will be documented by a Failure Report as described above. Failure reports and closeouts will be signed by the FRB chairman and submitted to the Project for final approval. Reports not dispositioned within 30 calendar days shall be considered approved.

7.9.2.3 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. The status of any such action will be reported at the PDR and CDR.

7.10 Inspections and Tests

UCB will plan and implement an inspection and test program which will demonstrate that applicable requirements are met.

Inspection and in process testing will be completed prior to installation into the next level of assembly. Inspection points and in process test requirements will be documented in assembly procedures and in the manufacturing certification logs discussed above in section 8.9.

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.

An end-item inspection will be performed on each component by the responsible engineer. It will be verified that the configuration is as specified in the master drawing list described in section 8.3, that workmanship standards have been met, and that test results are acceptable. All workmanship standards will be met according to the PAR, section 2.2.

7.10.1 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.

7.10.2 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.

7.11 Configuration Management

The master indented drawing list described in Section 8.3 will be used to track the as-built instrument configuration listing, and to insure that it is in accordance with the current UCB-approved instrument configuration.

7.12 Metrology

The science requirement on the accuracy of the physical measurements made by HESSI is $\pm$20%. The laboratory instruments on which the accuracy of tests of the science payload made at UCB depend include DC and AC voltmeters, counters, oscilloscopes, and spectrum analyzers. Verification of the accuracy of this equipment to the necessary levels during engineering testing will be done by a combination of calibration by outside vendors and cross-checking of one unit against another.

Acceptance level testing at the component level will be done with instrumentation calibrated per Mil-STD-45662 A.

7.13 Handling, Storage, Marking, Shipping, Preservation, Labeling, and Packaging

7.13.1 Handling

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

7.13.2 Marking, Labeling, Packaging

Marking, labeling and packaging will meet the intent of MIL-STD-129. Secure storage areas for the HESSI equipment will be located at UCB.

7.13.3 Shipping

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

7.14 Government Property Control

UCB will 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.

7.15 End Item Acceptance

Prior to shipment of the HESSI Mission, the Acceptance Data Package will be assembled by the Project Manager and reviewed by GSFC QA at the Pre-ship review.

8. CONTAMINATION CONTROL REQUIREMENTS

Following the start of phase C/D, the UCB project will perform a study of the contamination requirements and develop a contamination control plan for the HESSI Mission. This plan is expected to be similar to that currently in force on the FAST instrument development programs at UCB.

9. SOFTWARE ASSURANCE

9.1 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 on HESSI which have proven to be successful on past programs.

No subcontracting of software development is planned; all work will be done in house by UCB personnel.

This plan shall apply to instrument and GSE software developed for the HESSI project at the University of California, Berkeley.

The instrument software is computer code which runs in the micro processor(s) which are a part of the flight experiment package. GSE software is that which runs in ground-based equipment and is used to collect and display data from the instrument during development at the UCB.

9.2 Software Development

Software will be developed at UCB/SSL by a small team of programmers (one to two). Control is maintained by the lead programmer who is responsible for maintaining the code and incorporating all changes at a single location.

9.2.1 Responsibilities

All UCB-developed software is the responsibility of the HESSI PI. He is responsible for approving the software functional requirements, and for approving any deviations to those requirements in the software implementation. The requirements document is developed by the programming team at UCB in close consultation with the PI and other investigators and engineers. Once the requirements are approved, the programming team at Berkeley begins developing code.

This team consists of a lead programmer, aided by at least one other programmer and under the supervision of the Project Manager at Berkeley. The lead programmer is responsible for developing, maintaining, and testing the code. Any code developed by other programmers must be integrated into the flight software by the lead programmer. The lead programmer will maintain configuration control of the code.

Acceptance testing of the software will occur at Berkeley, and will ensure that the code is thoroughly tested. To the largest extent possible, testing will be performed by personnel not responsible for the development of the code.

Testing will occur in stages as successively more complete versions of the code are developed. At each major revision, a copy of the code will be sent to GSFC for evaluation.

9.3 Documentation

The instrument and GSE software will be documented by the following:

Software Requirements Document:	Describes the functional requirements on the software to a level sufficient for a programmer to implement.
Software Acceptance Test Plan:	Describes the tests to be performed on the software prior to committing it to flight PROMS.
Software Description Document:	Describes the software as implemented to a level sufficient to allow any competent programmer to maintain the code and develop additions if necessary.
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.

The lead 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 consisting at a minimum of the PI and Project Managers at Berkeley and GSFC.

9.4 Software Design Reviews

Three reviews of the instrument system and GSE software will be held. The reviews will consist of a presentation by the developer to a review panel appointed by the Project, with back-up material, splinter sessions, and subsequent meetings as required to resolve any issues raised. The reviews will be held coincident with, and will be a part of the HESSI payload CDR, PER, and PSR activities.

9.5 Configuration Management

Configuration control on the software will be performed by the lead programmer, and any change requests or bug reports will be communicated to him. Version numbers will be assigned and maintained by the lead 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 lead programmer via the Problem/Failure Report system. The lead 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 the lead programmer, the Berkeley Instrument Project Manager, and the PI. The lead programmer shall maintain a log book 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 PI, 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 lead programmer will implement the fix and issue a new release. The new release will be submitted to a full acceptance test (to be determined by the programmer, based on the nature of the fix) before again committing to PROM.

Any code to be uplinked after launch will 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

Appendix B GLOSSARY

Acceptance Tests: The process that demonstrates that hardware is acceptable for flight. It also serves as a quality control screen to detect deficiencies and normally to provide the basis for delivery for an item under the terms of a contract.

Assembly: A functional subdivision of a component, consisting of parts and subassemblies that perform functions necessary for the operation of the component as a whole. Examples are a power amplifier and a gyroscope.

Audit: A review of the contractor's of subcontractor's documentation or hardware to verify that it complies with project requirements.

Catastrophic: A potential failure effect which would result in complete loss of an item of hardware or a mission or result in serious injury to personnel, e.g., loss of ability to recover science data would be catastrophic to an instrument mission.

Critical: A potential failure effect which would result in a significant (as defined by the Project) performance degradation of an item of hardware or a mission.

Collected Volatile Condensable Material (CVCM): The quantity of outgassed matter from a test specimen that condenses on a collector maintained at a specific constant temperature for a specified time.

Component: A functional subdivision of a subsystem and generally a self-contained combination of items performing a function necessary for the subsystem's operation. Examples are transmitter, gyro package, actuator, motor, battery.

Configuration: The functional and physical characteristics of parts, assemblies, equipment of systems, or any combination of these which are capable of fulfilling the fit, form and functional requirements defined by performance specifications and engineering drawings.

Configuration Control: The systematic evaluation, coordination, and formal approval/disapproval of proposed changes and the implementation of all approved changes to the design and production of an item, the configuration of which has been formally approved by the contractor or by the purchaser, or both.

Configuration Management: The systematic control and evaluation of all changes to baseline documentation and subsequent changes to that documentation which define the original scope of effort to be accomplished (contract and reference documentation) and the systematic control, identification, and status accounting and verification of all configuration items.

Derating: The reduction of the rating of a device to improve reliability or to permit operation at high ambient temperatures.

Design Specification: Generic designation for a specification which describes function and physical requirements for an article, usually at the component level or higher levels of assembly. In its initial form, the design specification is a statement of functional requirements with only general coverage of physical test requirements. The design specification evolves through the project life cycle to reflect progressive refinement in performance, design, configuration, and test requirements. In many project the end-item specifications serve all the purpose of design specifications for the contract and items. Design specifications provide the basis for technical and engineering management control.

Designated Representative: An individual (such as a NASA plant representative), firm (such as assessment contractor), Department of Defense (DOD) plant representative, or other Government representative designated and authorized by NASA to perform a specific function of NASA. As related to the contractor's effort, this may include evaluation, assessment, design review participation, and review/approval of certain documents of actions.

Destructive Physical Analysis (DPA): An internal destructive examination of a finished part or device to assess design, workmanship, assembly, and any other processing associated with fabrication of the part.

Discrepancy: See Non-conformance.

Effectivity: The point (in configuration evolution) at which a change or action becomes applicable to the hardware or software.

Electromagnetic Compatibility: The condition that prevails when various electronic devices are performing their functions according to according to design in a common electromagnetic environment.

Electromagnetic Interference (EMI): Electromagnetic energy which interrupts, obstructs, or otherwise degrades or limits the effective performance of electrical equipment.

Electromagnetic Susceptibility: Undesired response by a component, subsystem, or system to conducted or radiated electromagnetic emissions.

End-to-End Test: Test performed on the integrated ground and flight system, including all elements of the payload, its control, communications, and data processing to demonstrate that the entire system is operating in a manner to fulfill all mission requirements and objectives.

Failure: See Non-conformance.

Failure Modes, Effects, and Criticality Analysis (FMECA): Study of a system and working interrelationship or its elements to determine ways in which failures can occur (failure modes), effects of each potential failure on the system elements in which it occurs and on other system elements, and the probable overall consequences (critically) of each failure mode on the success of the system's mission. Criticalities are usually assigned by categories, each category being defined in terms of a specified degree of loss of mission objectives or degradation of crew safety.

Functional Tests: The operation of a unit in accordance with a defined operational procedure to determine whether performance is within the specified requirements.

Hardware: Physical items of equipment. As used in this document, there are two major categories of hardware as follows:
1. Nonflight Hardware: Development hardware not intended to fly, hardware of flight design but found to be of unsuitable quality for flight use, or hardware intended for use on the ground.

2. Flight Hardware: hardware to be used operationally in space. It includes flight instruments (experiments) and/or spacecraft hardware.

Inspection: The process of measuring, examining, gauging, or otherwise comparing an article or service with specified requirements.

Instrument A subsystem consisting of sensors and associated hardware for making measurements or observations in space. The flying portion of a flight experiment.

Margin: The amount by which hardware capability exceeds requirements.

Monitor: To keep track of the progress of a performance assurance activity: the monitor need not be present at the scene during the entire course of the activity, but he will review resulting data or other associated documentation.

Non-conformance: A condition of any hardware, software, material, or service in which one or more characteristics do not conform to requirements. As applied in categories-discrepancies and failures. A discrepancy is a departure from specification that is detected during inspection of process control testing, etc., while the hardware or software is not functioning or operating. A failure is a departure from specification that is discovered in the functioning or operation of the hardware or software.

Part: A hardware element that is not normally subject to further subdivision or disassembly without destruction of designed use.

Performance Verification: Determination by test, analysis, or a combination of the two that the spacecraft can operate as intended in particular mission; this includes being satisfied that the design of the spacecraft of element has been accepted as true to the design and ready for flight operations.

Qualification: The process of demonstrating that a given design and manufacturing approach will produce hardware that will meet all performance specifications when subjected to defined conditions more severe that those expected to occur during its intended use.

Redundancy (of design): The use of more than one independent means of accomplishing a given function.

Repair: The article is to be modified by established (customer approved where required) standard repairs or specific repair instructions which are designed to make the article suitable for use, but which will result in a departure from original specifications.

Rework: Return for completion of operations (complete to drawing). The article is to be reprocessed to conform to the original specifications or drawings.

Similarity, Verification By: A procedure of comparing an item verified. Configuration, test, data, application, and environment should be evaluated. It should be determined that design differences are insignificant, environmental stress will not be greater in the new application, and that manufacturer and manufacturing methods are the same.

Single Point Failure: A single element of hardware the failure of which would result in loss of mission objectives or the hardware, as defined for the specific application or project for which a single point failure analysis is performed.

Spacecraft: An integrated assemblage of subsystems designed to perform a specified mission in space.

Subassembly: A Subdivision of an assembly, Examples are wire harness and leaded printed circuit boards.

Subsystem: A functional subdivision of a spacecraft consisting of two or more components, Examples are attitude control, electrical power subsystems, electrical power subsystems, and instruments.

Temperature Cycles: A transition from some initial temperature condition to temperature stabilization at one extreme and then to temperature stabilization at the opposite extreme and returning to the initial temperature condition.

Temperature Stabilization: The condition that exists when the rate of change of temperatures has decreased to the point where the test item may be expected to remain within the specified test tolerance for the necessary duration of where further change is considered acceptable.

Thermal Balance Test: A test conducted to verify the adequacy of the thermal design and the capability of the thermal control system to maintain thermal condition within established mission limits.

Total Mass Loss (TML): Total mass of material outgassed from a specimen that is maintained at a specified constant temperature and operating pressure for a specific time.

Verification: See Performance Verification.

Vibroacoustics: An environment induced by high-intensity acoustic noise associated with various segments of the flight profile; it manifest itself throughout the payload in the form of directly transmitted acoustic excitation and as structure-borne random vibration excitation.

Witness: A personal, on-the-scene observation of a performance assurance activity with the purpose of verifying compliance with project requirements. (see Monitor).

Appendix C DELIVERABLE DATA

Item	Description	Qty	Act	Schedule
5	Failure Reports	2	R	Within 72 hrs
7	System Level and Engineering Peer Reviews	2	I	As determined by PI
17	Contamination Control Plan	1	AFR	Upon Request
21	Integration and Test, Plans and Procedures	2	AFR	Upon Request
24	Monthly Technical Progress Reports	5	R	Monthly
PASV	Document the Configuration Management system	1	R	7/31/1998 (PDR)
PAF5	Mission Operations Autonomy Plan	1	I	7/31/1998 (PDR)
PAF8	Systems Engineering Plan	1	I	7/31/1998 (PDR)
PAF11	Critical Suppliers List and Audit Schedule	1	I	7/31/1998 (PDR)
PAF10	Launch Vehicle Separation Sequence	1	I	7/31/1998 (PDR)
4	Performance Assurance Implementation Plan	2	R	7/31/1998
8	Preliminary Design Review (PDR) / Confirmation Review	1	R	7/31/1998 (PDR)
13	Preliminary Safety Assessment	2	R	7/31/1998 (PDR)
15	Preliminary EEE Parts List	1	I	7/31/1998 (PDR)
16	Preliminary Materials List	1	I	7/31/1998 (PDR)
PAF6	Document Risk Assessment Descope Plan (Confirmation Review)	1	R	8/17/1998 (CR)
6	Failure Mode and Effects Analysis	2	R	10/31/1998 (CDR
9	Critical Design Review (CDR)	1	R	10/31/1998

18	Verification Matrix	2	R	10/31/1998 (CDR
19	Environmental Test Matrix	2	R	10/31/1998 (CDR
20	Verification Procedures	2	AFR	10/31/1998 (CDR
22	Orbital Debris Report	1	R	12/31/1998 (CDR+60)
14	System Safety Implementation Plan (SSIP) a) Ground Operations Procedures b) Safety Data Package (EWRR 127-1) c) Launch Site Data Plan (EWRR 127-1)	2	A	1/1/2000 (PER–3
10	Pre-Environmental Review	1	R	1/31/2000
11	Pre-Ship Review	1	R	5/31/2000
12	Flight Readiness Review	1	R	7/31/2000
23	Acceptance Data Package	1	AFR	7/31/2000 (L+30)
25	Final Phase B/C/D Technical Report	6	R	8/31/2000 (L+60)

Requirement Sources:
# == Contract Deliverable #
E.6 == Contract Section
L1 == Level 1 Requirements Document
PASV = Phase A Site Visit
PAF# = Phase A Findings #
Requirement Codes:

R (Review) - Documents in the category are to be reviewed within 10 working days by the GSFC or its desigı order to determine contractor effectiveness in meeting contract objectives. When Government review reveals . contractor may be requested to correct the inadequacies.

I (Information) - Documents in this category are to be provided to GSFC or its designated representative for i No Government response is required.

A (Approve) - Documents in this category require review and approval by GSFC or its designated representat implementation. GSFC shall approve/disapprove within 10 working days or receipt. Requirements for resubm letter(s) of disapproval.

AFR (Available for Review) - Documents in this category are to be available at the contractor's facility for rev request.