IMP-565-DOC
STEREO IMPACT Boom Protoflight Qualification Report

Revision Log:

Revision	Date	Remarks
--	8 April 2004	Baseline Release

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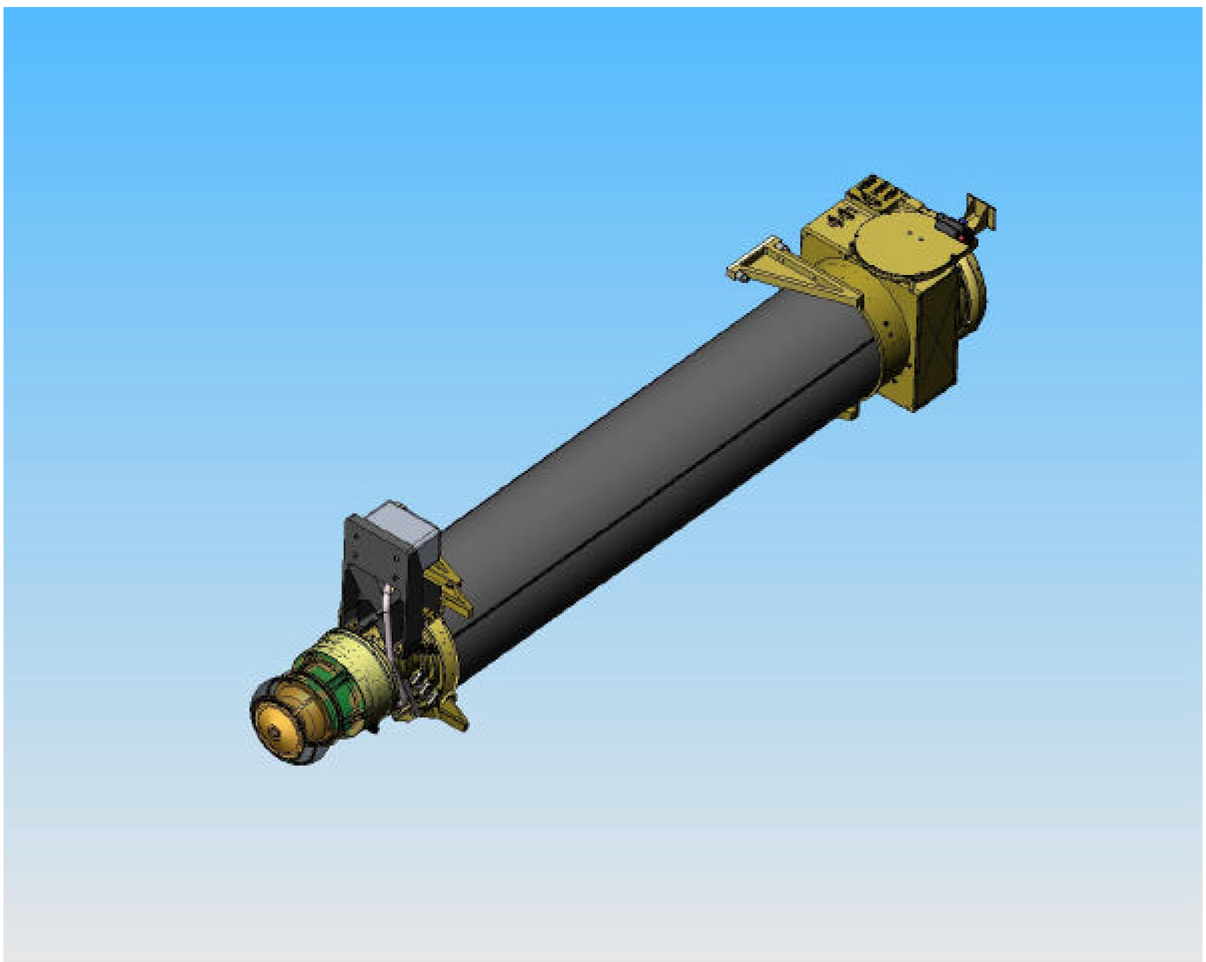

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1. Scope

This document reports the results of the Qualification Testing (Qual) for the Protoflight STEREO IMPACT Boom deployable mechanical assembly (Boom). The Boom is designed, assembled, tested, and verified for flight use to applicable project standards by the Space Sciences Lab (SSL) at the University of California, Berkeley (UCB).

2. Hardware Description and Assembly

2.1. Description

The Boom is a completed STEREO Boom mechanical assembly, consisting primarily of a compact nested series of composite tubes and mechanical releasing devices with instrument mass dummies and blankets as appropriate. The primary requirement of the device is to provide a compact structure during satellite integration, test, and launch and deploy in orbit to extend the Magnetometer approximately 3 meters and the SWEA approximately 4 meters from the spacecraft.

The Boom Assembly has two configurations, Stowed and Deployed. The Stowed configuration (integration and test) is as shown above. The entire unit weighs approximately 14.6 kg with instruments or mass dummies.

The Deployment of the Boom must take place in the vertical configuration to offset the effects of one (1)g loading. To achieve this testing, in addition to the Boom Assembly, the test set-up has a counterweight system designed by UCB to allow removal of gravitational loading on the Flight Hardware during deployment testing. (The system was designed for deployment in zero gravity and may not be deployed at one (1) g.)

2.2. Assembly Configurations

The assembly, dependent on activity, will have different configurations based on hardware being added and/or removed as appropriate. This includes full-up flight configuration, one with blankets removed, and one with preamp removed, for example. The following matrix lists all assembly configurations that will be used in the verification testing program.

#	Name	Where Used	Components Included	Components Not Included
1	Flight Configuration	Integration Onto S/C at JHU/APL	Boom, Harnessing, Instruments, Blankets	--
2	Acceptance Configuration	All vibration & thermal vacuum operations at UCB/SSL	Boom, Harnessing, Mass Dummies or Instruments as required	Thermal Blankets
3	Qualification Configuration	All vibration & thermal vacuum operations at UCB/SSL	Protoflight Boom, Harnessing, Mass Dummies	Thermal Blankets, Instruments
4	Thermal Balance Configuration	At UCB/SSL	Protoflight Boom, Harnessing, Mass Dummies, EM blankets	Instruments

3. Hardware Heritage

The Boom assembly shares design and component flight heritage with many previous programs built by UCB. Where possible, previous designs, components, analysis, and procedures will be utilized. These have recent NASA heritage with several rocket booms, the FAST axial booms, the Polar axial booms, and UoSat Gravity Gradient Booms (in the UK).

4. Reference Documents

Organization	Document	Title
APL	7381-9003	STEREO Environmental Definition, Observatory, Component and Instrument Test Requirements
APL	7381-9006	STEREO Contamination Control Plan
APL	7381-9012	STEREO IMPACT Interface Control Document
APL	7381-9030	STEREO EMC Control Plan and EMI Performance
APL	SOW#2009	FMEA for S/C Portion of Stereo
APL		Magnetometer Alignment Provisions, by Doug A. Eng
GSFC	463-ANYS-001	FMEA for … Instruments for Stereo Observatory
GSFC	GEVS-SE Rev. A	General Environmental Verification Specification
Swales	SAI-TM-STTE-001	UCB Deployable Contamination Test Results
Orbital		STEREO/IMPACT BOOM THERMAL BALANCE TEST PLAN, 29 August 2003, By: A. Seivold, OSC
Orbital	03-ALS-7295	IMPACT Boom Thermal Balance Test And Thermal Analysis Report
UCB	STEREO-IMPACT-PAIP	STEREO Product Assurance Implementation Plan
UCB	STEREO IMPACT Verification Matrix 2003-1-8	STEREO/ IMPACT Requirements Verification Matrix
UCB	IMPACT CM Plan, STEREO/IMPACT	Document Configuration Management Plan
UCB		Resonance Calculations IMPACT.Boom.res, By: S. Bale
UCB	IMP-001	STEREO IMPACT Boom ICD, Rev. F
UCB	IMP-448-DOC	STEREO Boom Vibration Report, Rev. A
UCB	IMP-449-DOC	STEREO IMPACT Boom Stowing Procedure, Rev. D
UCB	IMP-451-DOC	STEREO IMPACT Boom Deployment Checklist, Rev. E
UCB	IMP-452-DOC	STEREO IMPACT Boom Assembly Procedure
UCB	IMP-562-DOC	STEREO Boom Vibration Test Procedure
UCB	IMP-563-DOC	STEREO Boom Thermal Cycling Test Procedure
UCB	IMP-564-DOC	STEREO Boom Thermal Cycling Report, Rev. A
UCB	IMP-566-DOC	STEREO Boom Deployment Log

5. Qualification Methodology Overview

The verification methods used in the design, development, and building of the Boom will include all standard UCB/NASA program routines: peer design reviews; hand engineering analysis; use of preferred parts, materials, and vendors; testing to written procedures and plans; and test reports; inspections by in-house staff and outside services; computer analysis for dynamics and stress; and final reporting documentation.

The verification process consists of three main elements: analysis and design, qualification testing, and acceptance testing. All work was performed by UCB personnel, with external services utilized as required.

The basis for verification of the system is to “test as flown”. Tests performed that are not based on expected environs during launch and operation are not included. For example: the unit will be vibrated then cycled in thermal vacuum, with the first deployment occurring after survival temperature cycle, as that is the sequence which the unit will experience when flown.

6. Documentation

Documentation is maintained for all critical verification steps and will be available to interested project personnel.

Documentation consists of test plans, test procedures, engineering fabrication drawings, assembly procedures, test reports, test data sheets, unit logbooks, and photos. Engineering Documentation intended for use by outside personnel (vibration testing, fabrication drawings) shall be formal documents released via the UCB document release process. Master mark-ups and logbooks will be utilized in-house to speed development efforts where prudent. All documentation shall be maintained by UCB and be made available electronically where possible. Relevant build and test data shall be delivered with flight units as part of an End Item Data Package (EIDP).

7. Analysis and Design

7.1. FEM Analysis Summary (From "Report on Finite Element Modal Analysis of STEREO IMPACT Boom, Prepared by Robert Besuner, May 28, 2002")

"Finite element analysis (FEA) was done to determine the natural frequencies and mode shapes for the current design of the STEREO IMPACT boom in stowed, properly deployed, and improperly deployed configurations. The properly deployed configuration was analyzed using two different inter-segment joint stiffnesses (9850 N-m/rad and 13000 N-m/rad). The improperly deployed configuration assumes the first joint's latch pins do not engage their receptacles, causing a much lower joint stiffness (550 N-m/rad) for that joint, while the other joints have a stiffness of 9850 N-m/rad. Mode shapes are illustrated in the results section of this report, and frequencies are listed in this Summary section.

"The first three vibration modes in the stowed configuration involve combinations of bulging of tubes and bending and twisting at the SWEA end of the boom. The first three natural frequencies in the stowed position are 60.2, 81.8, and 83.4 hertz.

"The first six vibration modes in each of the deployed configurations are actually three pairs of orthogonal modes. That is, the first two modes are nearly identical to each other in shape and frequency, but occur in orthogonal planes. The same is true for the third and fourth and for the fifth and sixth modes. The results for the two properly deployed configurations fundamentally differ only in frequency. The mode shapes for the improperly deployed configuration are noticeably different from those for the properly deployed configuration, but are still generally similar. The mode shapes for the first two frequencies comprise simple cantilevered swaying of the Stacer and the telescoping boom components together. The next two modes are basically the Stacer oscillating transversely with fixed-fixed end constraints, independent of the telescoping segments. The next two modes have both the Stacer and telescoping portions in 'S' shaped oscillations. The first six frequencies for the properly deployed boom with joint stiffnesses of 9850 N-m/rad are 1.38, 1.38, 3.93, 3.93, 9.01, and 9.01 hertz. With joint stiffnesses of 13000 N-m/rad, the first six frequencies are 1.54, 1.55, 3.93, 3.93, 9.56, and 9.57 hertz. The first six frequencies for the improperly deployed boom are 0.473, 0.473, 3.92, 3.92, 7.53, and 7.53 hertz."

For the stowed configuration, the FEM analysis was verified by sine vibration testing. Vibration testing yielded first frequencies of 114, 92, and 75 Hz for the X, Y, and Z axes, respectively. Differences resulted from the unknown stiffness of the stowed configuration.

The EM meets the requirement of having a first resonant frequency greater than 50Hz. UCB has provided completed FEM model to APL for incorporation into the higher-level spacecraft model and is supported by UCB as requested. For the deployed configuration, the FEM analysis was verified by measuring first natural frequency mode via a one-axis accelerometer and conditioning electronics at UCB. The testing has confirmed a value of approximately 1.9 Hz.

7.2. Stress Analysis

Major components were analyzed to ensure positive strength margins. Loading inputs were based on expected inertial loads and operational loads as applicable. Stress analysis used classical methods

(Bruhn; Roark) and FEM computer modeling. The hand / spreadsheet calculations are used for 'first cut' sizing of critical components, and as such exist in the chronological file of the project. These sized components are then analyzed by FEM, and verified by testing.

7.3. Design Reviews

The Boom assembly has been reviewed by UCB project personnel and outside independent reviewers several times to ensure requirements and design intent are met. All reviews were presented with a design review package, and subsequent meeting minutes including action items were issued.

As of this release, nine UCB/SSL reviews of this program have been completed. Review data packages are available at UCB, as well as the Review Panel upon request.

Design review listing is as follows.

Date	Title
11 Sep 2001	Preliminary Design Review
23 Apr 2002	Peer Review #1
29 Oct 2002	Peer Review #2
20-22 Nov 2002	Critical Design Review
12 Mar 2003	Peer Review #3
4 Jun 2003	Boom Status/Planning Meeting
21 Aug 2003	Qual Boom Test Results Review
14 Jan 2004	Pre-Environmental Review
19 Apr 2004	Boom/STE-U/Mag Technical Readiness Review

7.4. Stiffness Analysis

Analysis of the deployed Booms' stiffness was made by classical calculation (via Excel spreadsheet), computer FEM means, and test measurements of similar Boom hardware (prototypes and engineering models). Analysis shows a first frequency which meets the requirement of being greater than 0.5 Hz

7.5. Deployment Force Margin Verification

A key component of a successful in-flight Boom deployment relies on sufficient margin of output (Stacer) force compared to deployment drag. Calculations and test data were used to quantify and optimize each parameter to ensure large margins. The minimum ratio for all flight units in the worst case (test verified) is 3 (per GEVS Section 2.4.5.3). Force Ratio is defined as Force Available/Force Required. (Note: Force Margin is defined as Force Ratio minus 1.0.) In the specific case of the Boom deployment, Force Available is Stacer output and Force Required is the sum of the drag of the Stacer, the rolling friction of the Lock Pins and the drag to extend the harness. Velocity is controlled by adding drag through a Flyweight Brake. The drag goes to 0 when the velocity slows to under ~ 0.5 meters per second. Test deployments of subassemblies and of the entire Boom assembly verify the Boom maintains a Force Ratio greater than 3.

7.6. FMEAnalysis

Failure Modes Effects Analysis (FMEA) was performed by the Applied Physics Laboratory at Johns Hopkin's University (APL), for spacecraft and instruments, and Goddard Space Flight Center (GSFC), for instruments, to analyze possible failure modes, apply trade studies of mitigation, and uncover any overlooked characteristics of the design. These analyses were released in documented reports (see Section 4 for references). The FMEA included the issues of incomplete deployment, temperature effects, failure of deployment, tube buckling and other characteristics. UCB has provided and shall continue to provide input (design information, test data, heritage data, analysis, etc.) to this effort as requested.

8. Documentation, Parts Selection, Build Controls

8.1. Parts and Materials Selection

Where possible, parts and materials of type with recent flight heritage will be used. A parts and materials listing is maintained, available for inspection, and submitted to GSFC for evaluation. All parts were scrutinized for conformance to vacuum applicability, thermal environment, compatibility with mating parts, and general applicability to program requirements.

8.2. Drawing Documentation and Control

All parts are fabricated to engineering drawings consistent with MIL-STD-100, ANSI Y14.5 and UCB/STEREO Configuration Management Plan (IMPACT CM Plan). Drawings are formally released; all revisions controlled by the cognizant UCB engineer and are available to the Project if requested.

8.3. Component Parts Inspection

All incoming hardware is inspected prior to use. Inspection consists of visual inspection and measurement, logging and review of certifications and test data and check of conformance to UCB Performance Assurance Implementation Plan (PAIP). Critical parts will be completely inspected prior to further processing.

8.4. Assembly Controls and Inspection

All critical assembly and test procedures have documented procedures. Travelers consisting of procedures, certifications, and drawings have been maintained with the flight hardware.

8.5. Final Assembly Inspection

Flight Models will have a final inspection to verify: dimensions on interfaces and envelope, mass properties, and overall quality. Closeout photographs will extensively document the final flight build.

9. Mass Properties

Flight Models will have mass properties of total mass and center of gravity (both stowed and deployed configurations) measured. Mass will be accurate within 500 grams and Center of Gravity within 6.35 mm. Moment of Inertia will be analyzed with a goal of accuracy within 10%.

10. Functional Verification Testing

10.1. Deployment Functioning Overview

10.1.1. Full Deployment

The Boom underwent a large number of test deployments (>28) to verify functionality. A full deployment is defined as actuation via powering the SMAR (Shape Memory Alloy Release) pin puller, Stacer initiation via Deployment Assist Device (DAD), full deployment of the Stacer, extension of all tubes and locking of all Lock Pins. All full deployments were made with the Boom in the Vertical position with a g-negation fixture attached. The Boom underwent more than 18 full deployments during Qual. The Flight Models will be deployed a minimum of 4 full deployments.

10.1.2. First Motion

'First Motion' activation—power up of the SMAR actuator to allow small (10 millimeters or less) movement in the retraction pin—can be performed on the two sets of Flight Models during Spacecraft Integration and Testing. This first motion activation verifies proper actuation of the pin puller without Boom deployment and stowing. The SMAR pin must be reset. This test was utilized several times to verify the correct resetting of the SMAR.

10.2. Monitoring and Data Collection

Deployments were monitored as completely as possible, depending on test locality. All in-air deployments had real-time visual inspections. Rate monitoring and alignment checks were provided as available. In-vacuum deployments were visually verified and the deployment time measured in-situ, as allowed by chamber constraints.

10.3. Component Monitor

Where useful, individual components were monitored to determine baseline characteristics for Flight and Protoflight units, i.e.: Boom stiffness, length etc.

10.4. Deployment Length

The length of the fully deployed Boom meets the length requirements of 1) the Magnetometer must be greater than 3 meters from the space craft and 2) the Magnetometer must be greater than 1 meter from any other instrument. The fully deployed Boom also meets the requirement of an unobstructed SWEA field of view.

10.5. Deployment Rate

The deployment rate will be calculated from the deployment time on all units at all deployments. There is no requirement for the deployment rate; the design goal is approximately 1 meter per second.

10.6. Boom Stiffness Verification

All Flight Models will be tested for actual stiffness following full deployment. Stiffness verification to consist of resonant Sine test (first natural frequency measured) using an accelerometer and associated electronics at the end of the Boom. See Section 18.2 for measured stiffness data analysis.

10.7. Boom Deployments

The Protoflight Boom was deployed as defined below.

Design	Post Build Deploy	Shock	Alignment	Thermal Vacuum Deploy	Post Vibe	Deploy Rate	Force Margin	Other
1,2,3	26	4, 5, 6, **9**	7, 8, 22, +	10, 11*, 12*, 13	**9**	19, 22, 26, **27**	14, 15, 16, 17, 20, 21, 23, 24, 25, **27**, 28	18

* Cold deploy froze. See PFR-1001.
** **Bold** indicates deployment is in multiple columns.

11. Spacecraft and Launch Vehicle Compatibility Testing

11.1. Vibration

Vibration testing was performed on the Boom at an outside vendor to verify unit dynamic and structural adequacy. All testing is consistent with GEVS requirements and APL 7381-9003 (including coupled loads analysis). All vibration testing was performed with Booms in stowed configuration.

See Attached: UCB Document "IMP-562-DOC, STEREO Boom Vibration Test Procedure".

11.2. Thermal Vacuum Testing

The Qualification Unit was vacuum tested: thermal balance, thermal cycling, and deployment. All Thermal Vacuum Testing was performed at UCB in the chamber built by the project for that purpose. This chamber allowed pump down to hard vacuum, thermal cycling (hot and cold), and full deployment under vacuum.

Complete Thermal Vacuum test plan as contained in UCB Document “IMP-563-DOC, STEREO BOOM Thermal Vacuum Cycling Test Procedure, By: W. Donakowski, 08 August 2003” (Attached). The complete thermal balance test plan is contained in “STEREO/IMPACT Boom Thermal Balance Test Plan, 29 August 2003, By: A. Seivold, OSC” (Attached).

11.3. Resistivity

11.3.1. Surface Resistivity

Following flight build, exterior assembly surfaces will be checked in various locations on the exposed outer surfaces to verify a surface resistivity of less than 10^8 ohms / sq. for Flight Units. Surface resistivity was verified as below requirements for the carbon composite tubes during fabrication.

11.3.2. Ground Resistivity

To verify adequate grounding of the flight units, the assembly shall be checked for resistance from external surface to spacecraft deck, not to exceed 2.5mOhms per APL Specification.

11.4. EMI/EMC

Testing to be performed at an outside facility (GSFC or JHU-APL).

11.5. Magnetics Cleanliness

To verify all Boom components are magnetically low permanence, a ‘Magnetics Cleanliness’ test shall be performed at UCB during and following assembly activities. Equipment for this verification is provided by GSFC consisting of a cylindrical shell around a sensor head capable of measuring ~5nT. This test will be performed at UCB/SSL.

11.6. Cable Harness Connectivity

To ensure cable harness (Spacecraft to Instruments) integrity, the connector designators used shall be included in the Interface Control Document (ICD).

11.7. Spacecraft End-to-End Electrical Connectivity

As part of the integration activities, UCB shall provide a GSE Flight-like SMAR (with connectors) to the Spacecraft vendor for electrical connectivity check-out as deemed appropriate.

11.8. Boom Alignment

The Boom is required to align the Magnetometer to within 1° of the spacecraft reference frame. Alignment will be checked following several Boom deployments to assure repeatability. Requirements are fully specified in “Magnetometer Alignment Provisions, by Doug A. Eng, APL/JHU.”

See Section 13.9.

11.9. Self-Induced Shock

Boom deployment results in self-induced shocks as the deploying element is released by the SMAR, and when reaching end of travel limit for each tube. Per GEVS 2.4.4.1 and 7381-9003 (paragraph 2.4.4) the Protoflight Model will undergo self-induced shock testing with instruments installed to verify they will present no degradation to the Boom itself or the instruments from these nominal events. This test was performed once on the Protoflight Unit with instrument mass dummies.

See Sections 13.8 and 18.1.

11.10. Boom Deployment following Spacecraft Integration

The Boom will be deployed for Spacecraft EMC. A First Motion test will be done to check the actuator. Then, the Boom will be deployed by hand for guidance and g-negation. The Boom must then be removed from the Spacecraft, stowed, and reintegrated onto the Spacecraft.

12. Contamination

12.1. General Guidelines

Flight hardware will be assembled clean prior to arrival at test facility. For the majority of the testing, the Components shall be maintained in a Class 10,000 Clean Room or better. For short periods (loading/unloading into chamber, short transitions) the components may be exposed to Class 100,000 Environment. The Flight Hardware shall be double-bagged with Llumalloy bagging material or equivalent whenever outside a Class 10,000 clean room following thermal vacuum bakeout.

In an effort to establish baseline contamination data, the Boom was surveyed for contamination by Swales Aerospace. The report results stated ‘contamination levels for all samples were not below the level 300 goal set for the survey. However, it is believed that the Booms will not generate enough particle contamination during deployment to pose a threat to the contamination sensitive instruments on STEREO’. See referenced Swales document for complete survey data.

12.2. Materials Outgassing

12.2.1. Materials Selection and Listing

Boom materials make use of low outgassing materials throughout as defined in NASA NRP 1124. A complete listing of the materials used in the Booms shall be maintained by UCB. This listing has already been provided to the GSFC materials branch for evaluation and comment.

12.2.2. TQCM Monitored Bakeout

No requirement for Protoflight.

12.2.3. Materials Samples Program

UCB shall maintain samples for all materials whose outgassing properties may require validations at a later date if outgassing events occur. Specifically, all materials requiring mixing (2 part epoxies, potting, coatings, and the like) and all composite materials will have samples maintained by UCB. All samples to be dated and serialized to verify traceability to flight hardware components. Unless requested, UCB does not plan to routinely test each sample for outgassing characteristics or material properties.

12.3. Clean Room and Facility Monitoring

12.3.1. Clean Room Operations

During all Clean Room operations, a calibrated particle counter will periodically survey the environment near the flight hardware to verify particle counts are sufficiently low.

12.3.2. TQCM Monitoring

No requirement for Protoflight.

12.3.3. Empty Tank Certification

Prior to the start of acceptance testing, the tank shall be cleaned by the facility and certified via TQCM means to verify cleanliness. Level of Cleanliness shall be less than 100 Hz/hour with a 15 MHz TQCM at -20°C and the chamber at qualification conditions. On 25 March 2004, the background reading of the chamber in this condition was recorded as 52 Hz/hour.

12.3.4. Post-Assembly Cleaning and Inspection

Following functional testing and prior to input to vacuum tank, the Booms were manually cleaned using vacuum cleaning with ULPA filtered vacuum and alcohol wipe. Following cleaning, the unit was inspected for contamination with a black light and cleaned as necessary in compliance with APL Contamination Control Plan, 7381-9006.

12.3.5. On-site Transportation and Handling

N/A for Protoflight.

12.3.6. ESD Control Plan

All work (build, handling, testing, transport) of the Boom hardware is unaffected by ESD. Precautions will be made for the handling of the instruments when incorporated into the assembly, per the UCB ESD Plan

13. Qualification Testing of Engineering Model Unit Results

13.1. Functional (Deployment)

Greater than 28 deployments of the Boom were completed; at least 18 of those were full deployments. The Boom was fully deployed under vacuum in the Vertical position twice; once hot and once cold. Mass models were installed to represent the mass of the instruments which were not present.

Pass / Fail Criteria (P/FC): Magnetometer > 3m from spacecraft, > 1m from other instruments; First Resonance (Natural Frequency): > 0.5. The upper resonance limit has not been formally established, but the Boom must not have a resonance near any other component on the S/C (i.e. solar panels, SWAVES antennas, etc.). Length: 4.26 meters (deployed section); Resonance data, avg value: 1.9 Hz (See Section 18.2). 6.7 seconds average deployment time, => 0.6 meters per second deployment velocity

Deployment Summary Table

Number	Date	Time	Deploy	Actuation	Test Purpose:	Time
1	06/03/03	15:39	FULL	Manual		
2	06/03/03	17:59	FULL	Manual		
3	06/04/03	11:53	FULL	Manual		

4	07/16/03	16:29	FULL	Actuator	Shock - missed actuation	
5	07/17/03	12:00	FULL	Actuator	Shock - no data	
6	07/17/03	18:30	FULL	Actuator	Shock - Ch1&3 poor, Ch2 (Mag) OK	
7	07/18/03	9:30	FULL	Actuator	Photogrammetry Followed	
8	07/18/03	20:00	FULL	Pull-out	Photogrammetry Followed	
9	07/31/03	14:43	FULL	Actuator	Post-Vibration, Shock - data good	
10	08/14/03	10:55	FULL	Actuator	Thermal Vac, Hot Deploy @ 40C	
11	08/15/03	9:55	Actuator Only	Actuator	Thermal Vac	
12	08/16/03	9:05	Actuator Only	Actuator	Thermal Vac	
13	08/17/03	10:37	FULL	Actuator	Thermal Vac, Cold Deploy @ -33C	
14	08/19/03	14:00	FULL	Pull-out	Load Determination	
15	08/19/03	16:00	FULL	Pull-out	Load Determination	
16	08/19/03	18:30	FULL	Pull-out	Load Determination	
17	11/03/03	14:30	See Notes	Actuator	Margin Test #1	
18	11/04/03	10:30	FULL	Actuator		
19	11/04/03	15:20	FULL	Actuator		7.5 s
20	11/06/03	13:23	FULL	Actuator	Margin Test #2	
21	11/06/03	15:30	FULL	Actuator	Margin Test #3	
22	11/12/03	13:05	FULL	Actuator	Mag Alignment #1	5.9 s
23	11/12/03	14:30	FULL	Actuator	Margin Test #4	
24	11/14/03	11:30	FULL	Actuator	Margin Test #5	
25	11/19/03	13:30	FULL	Actuator	Margin Test #6	
25a-c	11/25/03		See Notes	Manual	Margin tests of subassemblies	
26	12/10/03	11:30	FULL	Actuator		5.7 s
27	12/16/03		FULL	Actuator	Margin Test #7, Requirement Met	7.5 s
28	01/09/04	16:10	FULL	Actuator	Margin Test #8, Thermal Vac - Cold	

13.2. Magnetics Cleanliness

Protoflight unit will be tested to quantify magnetic signature of the Boom utilizing GSFC supplied magnetometer.
P/FC: Goal: <1 nanoTesla @ 1m.

Protoflight Unit was measured in July 2003 as <2 nanoTesla. Unfortunately, this was the limit of the magnetometer employed. Measurements were made a minimum of one (!) inch from the hardware. This is suitable for most of the Boom, but will require more resolution where parts are close to the Magnetometer.

13.3. Mass Properties

Mass properties were measured following assembly in stowed configuration and calculated in the deployed configuration.
P/FC: <= 12.1 kg.

Unit assembled, weighed with all hardware (mounting bolts and instruments excluded): 11.7 kg

13.4. Vibration Testing

Vibration Testing to Qualification Levels was performed on the Qualification Unit. Testing consisted of sine survey, sine strength, and random inputs. Vibration testing was performed to verify FEM analysis as well as structural adequacy of the Boom assembly design. All vibration testing was performed in the

stowed configuration. Test inputs per GEVS requirements and APL 7381-9003 and will be contained in a separate UCB test procedure.
P/FC: The Boom has successfully passed vibration testing if the unit is not degraded mechanically, functionally, or structurally. Success criteria shall consist of: No lost of functionality in Boom Assembly Deployment (testing to occur following testing at UCB), no significant change in pre- and post- sine sweep signatures, no permanent deformations, movements, or degradations, no loss of connectivity of cable harness (measured before and after each test).

The STEREO Boom vibration tests for the proto-flight boom were conducted July 21 through 23, 2003 at Wyle Laboratories in El Segundo, California. No anomalies noted. First stowed vibration modes were 114, 92, and 75Hz in the X-, Y- and Z-axis, respectively. FEA predict: 60.2, 81.8, and 83.4 Hz, respectively.

See Attached: UCB Document, “IMP-448-DOC, STEREO Boom Vibration Report, Rev. A”

13.5. Electrical Continuity Testing

Harness integrity was verified by visual inspection during the stow process after each deployment. No degradation was apparent.
P/FC: < 0.5ohms

13.6. Resistance / Capacitance

13.6.1. Surface Resistivity

Following flight build, exterior Boom surfaces will be checked in various locations on the exposed outer surfaces to verify a surface resistivity of less than 10^8 ohms / square for flight units.
P/FC: < 10^8 ohms / square.

Requirement met. Measurements made at various points on deployed unit. All < 10^3 ohms / square.

13.6.2. Ground Resistivity

To verify adequate grounding of the Qualification Unit, the Boom shall be checked for resistivity of less than 2.5mOhms following flight build, from any point on the unit to the mounting plate.
P/FC: Resistivity of less than 2.5mOhms following flight build, from any point on the unit to the base plate.

Requirement met. Ground strap designed, fabricated and measured. Awaiting location by APL.

13.7. Thermal Vacuum

The Boom underwent vacuum testing, including thermal balance, deployment, and thermal cycling. All thermal vacuum testing was performed at UCB in the environmental chamber built by the project for this purpose. The chamber allowed pumping down to hard vacuum, thermal cycling (hot and cold), and full deployment under vacuum. Complete thermal vacuum test plan as contained in UCB Document “IMP-563-DOC, STEREO Boom Thermal Cycling Test Procedure”.

See Attached: UCB Document “IMP-563-DOC, STEREO Boom Thermal Cycling Test Procedure”

13.7.1. Hot/Cold Soaks

The hot/cold soaks consisted of elevation to +40° C and decrease to –33° C for survival verification, then additional cycles at expected operational temperatures of +40° C and decrease to –33° C (per GEVS). At each temperature extreme, the unit was ‘soaked’ for a minimum of 2 hours. A total of 7 cycles were made. The hot/cold soaks were performed with the unit in the stowed configuration. All thermal vacuum hot/cold soaks as defined in UCB Document “IMP-563-DOC, STEREO Boom Thermal Cycling Test Procedure”.

See Attached: UCB Document “IMP-564-DOC, STEREO Boom Thermal Cycling Report, Rev. A”

13.7.2. Thermal Balance

The Boom underwent thermal balance testing at UCB to: Verify the thermal model, verify the thermal design of the IMPACT Boom pre-deployment configuration, determine the adequacy of the thermal blankets and measure the effective emittance, establish the adequacy of the Bobbin Cover MLI window surface property and predicted absorbed solar energy to maintain pre-deployment temperature levels, establish the adequacy of the thermal design to provide acceptable Instrument interface temperatures using dummy thermal/mass Instrument models, use the thermal balance data to verify and modify the Boom thermal math model, and determine the adequacy of the pre-deployment heater to raise pinpuller and housing temperatures to specified temperature levels in the specified time period.

The test was performed in the stowed configuration with 19 thermal monitors located on the hardware. Tests covered three cases: the cold operational case, the transient case of heating the pinpuller and the hot operational case. The Boom was complete with blankets, cables, and appropriate mass/model dummies for missing instruments. No sun simulator or facsimile was possible at the UCB facility.

See Attached: Orbital Document #03-ALS-7295, IMPACT Boom Thermal Balance Test And Thermal Analysis Report

13.7.3. Deployment

The Boom was deployed in vacuum during thermal vacuum testing at both hot and cold temps. The goal of testing was to verify no degradation in Boom function following thermal testing.
Pass / Fail Criteria (P/FC): Boom fully deployed;

1	14 Aug 03	Full Deploy Hot @ 40° C
2	17 Aug 03	Full Deploy Cold @ -33° C

13.8. Self-Induced Shock

The Boom was deployed to verify that the self-induced shock will present no degradation to the unit itself or the attached instruments. Shock data was gathered by three 1-axis accelerometers mounted as follows: 1) mounted to the STE-U instrument dummy at a mounting pedestal and oriented along the axis of the mounting pedestal, 2) mounted to the Magnetometer mass dummy and oriented along the axis of Boom deployment, and 3) mounted to the base of the SWEA and oriented along the axis of Boom deployment. Data was recorded via a digital acquisition device.

Maximum shock value occurred on the SWEA device at the end of stroke due to final lock-up of the Boom, as expected. The shock reached a magnitude of approximately 38 g. Shock data integrated into vibration spectrum of instruments. All shock power spectra are within the vibration spectra of the instruments.

P/FC: No degradation of function of the Boom or attached instruments.

See Section 18.1 for plots of the SWEA shock integration.

13.9. Boom Alignment

The Boom has been repeatedly shown to align the magnetometer to with 0.48°.

14. Test Order and Flow

See Section 19 for Flow Charts of test flow sequencing.

15. Data Collection and Documentation

All assembly procedures, certification logs, process certifications, test procedures and reports will be maintained and collected in one location by UCB.

16. Testing Verification Matrix

		Verification Matrix for STEREO/IMPACT/Boom																		Revision Date: 1/6/2004
																				Revision Number: 5
Hardware Description		Test																		
Level of Assembly	Item	Deploy Test, Room Temperature	Deploy Test, Thermal Vac	Stiffness, Proof Load	Vibration, Sinusoidal	Vibration, Random	Self Shock	Acoustics	Alignment	Force Margin Deployment	Thermal Vacuum	Thermal Cycle	Thermal Balance	End-to-End Conductance Test	EMC/EMI	Magnetics	Bakeout	Deployment Contamination	Contamination Inspection	Comments
C	Proto	**P**		**P**																
C	EM	**P**		**P**														**P**		Qual levels
C	PF/FS	**P**	**P**	**P**	**P**	**P**	**P**		**P**	**P**	**P**	**P**	**P**	**P**		**P**				Protoflight levels
C	FM1	X		X					X					X		X			X	Protoflight levels
C	FM2	X		X					X					X		X			X	Protoflight levels
S	FM1		S2		S1	S1	S				S2	S2			S		S2			Protoflight levels
S	FM2		S2		S1	S1	S				S2	S2					S2			Protoflight levels

Legend:

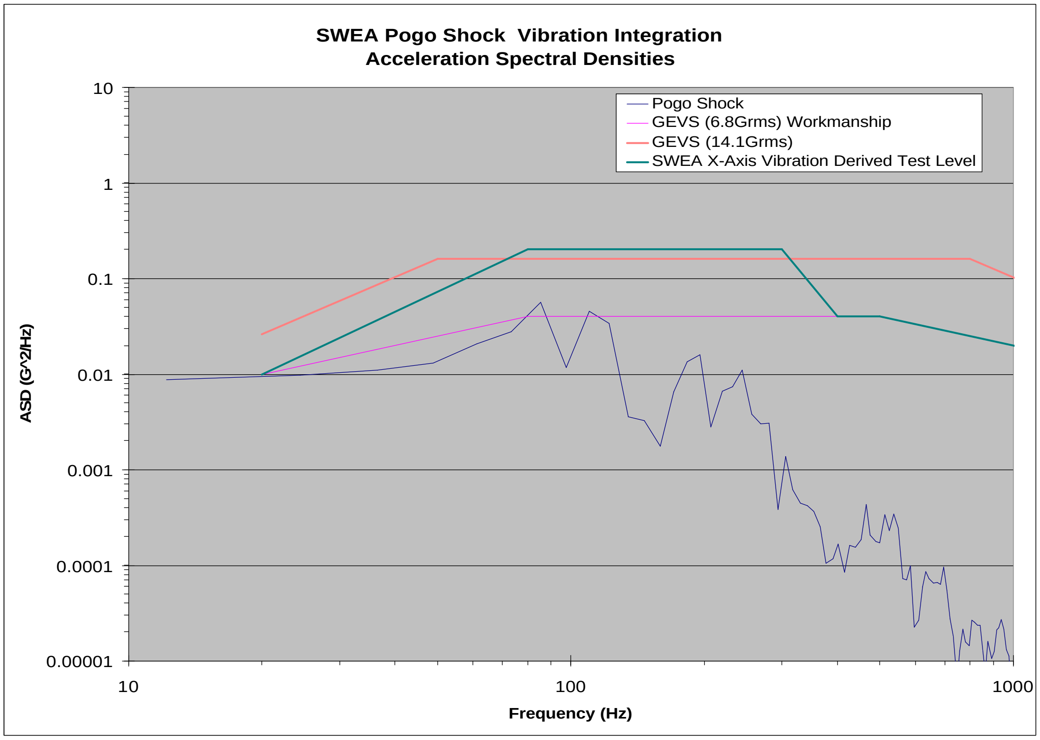
Level of Assembly	Unit Type		Status	
C = Component	PT =	Prototype	X =	Test required
S1 = with MAG, STE-U	PF/FS	Protoflight / Flight Spare	A =	Analysis
S2 - with MAG	FM1 =	Flight unit #1	**P = Performed**	
S = with all instruments	FM2 =	Flight unit #2		

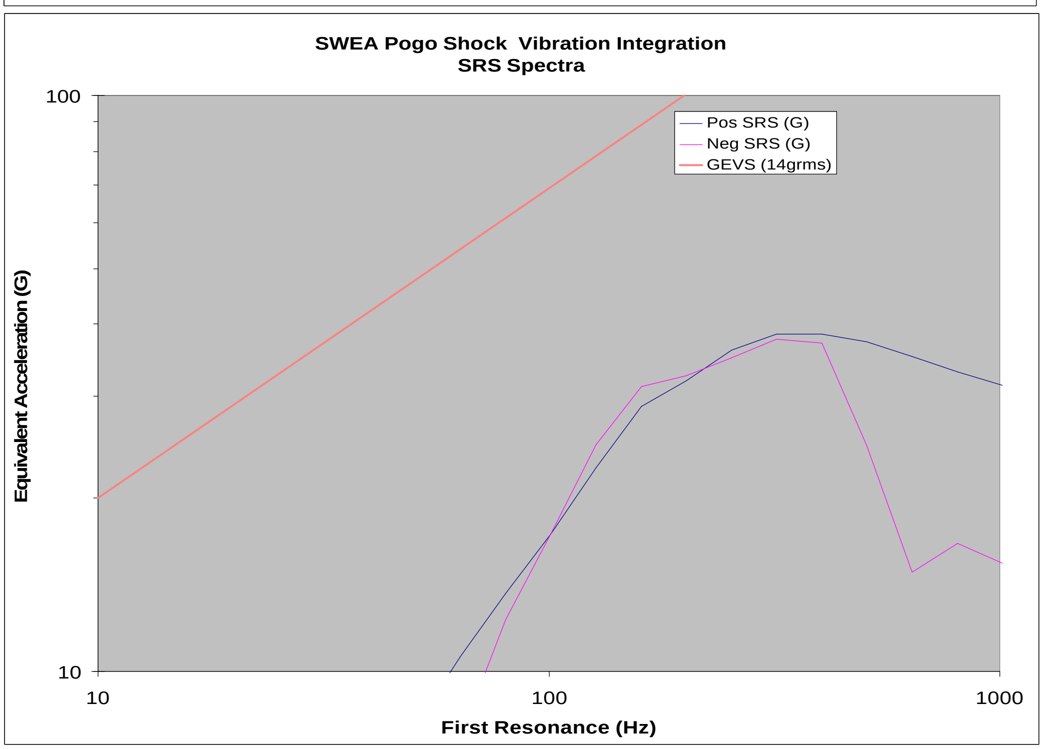
17. Hardware Interface Control Drawing

See Attached: UCB Document, "IMP-001, STEREO IMPACT Boom ICD, Rev. F"

18. Natural Frequency & Self-Induced Shock Plots

18.1. Self-Induced Shock Plots





Note: GEVS 14Grms line shown for comparison only.

18.2. Natural Frequency Analysis

IMPACT Boom resonance tests

	Test 1	Test 2	Test 3
f_1	1.9 Hz (0.526 s)	1.9 Hz (0.526 s)	1.94 Hz (0.517 s)
Δf (FWHM)	0.202 Hz	0.198 Hz	0.17 Hz
$\Delta f/f_1$	0.106	0.97	0.087
β	0.51 s^{-1} (1.96 s)	0.46 s^{-1} (2.19 s)	0.426 s^{-1} (2.35 s)
damping ratio	4 %	3.8 %	3.5 %

Notes:

1) wavelet transform is only valid within the black 'cone of influence' see on the spectrogram
2) wavelet amplitude (bottom panel) is the average amplitude between the dotted lines on the spectrum, slightly greater than the FWHM interval
3) the function $\exp(-\beta t)$ is fitted to the red part of the amplitude to obtain β
4) damping ratio is $1/\mathrm{sqrt}(1 + (\omega_1/\beta)^2)$

For more information, See Attached: UCB Document, "Resonance Calculations IMPACT.Boom.res.pdf, by Stuart Bale."

19. Testing Flow Chart, Protoflight (PF) Unit (Reference: Section 13)