THEMIS Instrument Payload
Environmental Verification Plan and Test Specification

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-	12/23/03	Draft Released	-
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TBD List

Identifier	Description

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1. Introduction

1.1 Overview

THEMIS is a NASA MIDEX mission which will launch a constellation of five micro-satellites (probes) in mid-2006. Flying in synchronous orbits within the earth's magnetosphere, the probes will measure the particle processes responsible for eruptions of the aurora. As the prime contractor for THEMIS, the University of California at Berkeley (UCB) provides the project management, systems engineering, flight instrumentation, ground-based imagers, mission operations, and performance assurance. Swales Aerospace provides the Probe Buses, Probe Carrier and leads the integration, test and launch processing activities. Key international partners include teams from Canada, France, Germany, and Austria.

1.2 Scope

This document provides a plan for verifying the performance and environmental test requirements levied on the THEMIS Instrument Payload. The Instrument Payload consists of the Instrument Data Processor (IDPU) and five instruments: the Electric Fields Instrument (EFI), the Electrostatic Analyzer (ESA), the Solid State Telescope (SST), the Fluxgate Magnetometer (FGM), and the Search Coil Magnetometer (SCM). The purpose of this plan is to describe the process through which UCB will (1) ensure the system is capable of surviving the predicted launch and space environment and (2) verify all elements of the system are compatible with each other and are capable of obtaining the required mission performance. The design and test requirements described in this document are consistent with the environments described in the Swales *Probe Bus and Probe Carrier Verification Plan and Environmental Specification (SAI-SPEC-TBD).*

1.3 Applicable and Related Documents

- **THEMIS Environmental Design Specification.** Specifies the environmental design requirements for the THEMIS Probes and the Probe Carrier, consisting of the natural on-orbit environments, as well as the Induced Environments (pre-launch, launch and ascent, and on-orbit).
- **THEMIS Probe Bus and Probe Carrier Verification Plan and Environmental Test Specification.** Defines the functional performance and environmental test requirements for the Probe and Probe Carrier. Requirements are specified for various levels of assembly including components, subsystems, and the Probe.
- **THEMIS Verification Matrix.** Provided as part of the THEMIS Mission Requirements Document (MRD). Indicates, in a tabular format, if each requirement is verified by test, analysis and/or inspection, and describes the test or analysis to be performed. References test procedures, calibration procedures, test reports, and/or analysis results.
- **THEMIS Environmental Test Matrix.** Lists environmental tests to be performed at all levels of assembly. Verifies that the environmental test program proposed complies with the general guidelines stated in the Goddard Environmental Verification Specification (GEVS-SE). As testing progresses, the ETM evolves into a summary of the environmental test program as run, with additional columns referencing the place and date of test, test procedures, test reports and any anomalies that may have occurred.
- **Goddard Environmental Verification Specification (GEVS).** Provides the environmental testing required for GSFC missions. Specification is used as a guideline in developing the THEMIS specific environmental test program.

1.4 Definitions

For the purposes of this document, the following definitions apply.

Levels of Assembly

Probe Carrier Assembly (PCA): The integrated system at launch. Includes the Probe Carrier and five Probes.

Probe: The integrated flight system. Includes the Instrument Payload and all support subsystems.

Probe Bus: The portion of the Probe that is integrated by Swales. Refers to all support subsystems required to accommodate the Instrument Payload.

Instrument Payload: The portion of the Probe that is integrated by UCB. Refers to the entire instrument suite.

Instrument: Defined by the five scientific investigations on THEMIS (EFI, SST, SCM, FGM, and ESA).

Component: A major distinguishable part of an Instrument (i.e. Spin Plane Boom (SPB) for the EFI, Pre-amplifier for the SCM, etc.)

Assembly: A major functionally complete part of an Instrument component (i.e. Boom Electronics Board (BEB) for the EFI, SPB Motor, etc.)

Sub-Assembly: The level below an assembly. Usually refers to a circuit board or a specific part of a mechanical assembly (i.e. Actuator for SPB Doors)

Hardware Units

Engineering Test Unit: Hardware that is built specifically for testing. Usually is a faithful representation of a flight unit (without flight quality EEE parts for example).

Flight Unit: Hardware that is planned for flight.

Qual Unit: An engineering unit built specifically for qualification testing.

2. Environmental Test Program

This section describes the environmental test program that will be conducted to verify that the Instrument Payload meets the environmental requirements of the THEMIS Mission. Verification at UCB begins with testing and inspection at the sub-assembly and assembly level and continues through full instrument payload functional testing after all environmental tests have been completed. Successful completion of the test program qualifies the Instrument Payload for delivery to Probe integration by demonstrating it meets specified performance requirements while being exposed to environmental conditions equal to or more severe than those expected during the mission lifetime. The following tests, demonstrations and supplemental analyses are required for Instrument components.

- Proof Pressure Test (if applicable) and Pressure Profile Verification Analysis
- Mass Properties Measurement
- Performance/Functional Test (including Life Test if applicable)
- Minimum Modal Frequency Verification
- Sine Burst Vibration Strength Test (unless qualified by analysis)
- Random Vibration Test
- Sine Vibration Test
- Thermal-Vacuum or Thermal Cycle Test
- Electromagnetic Compatibility
- Magnetic Cleanliness Verification

Formal tests are conducted at both the component level and the instrument level of assembly, in order to maximize the effectiveness of the tests and minimize the risk to the instrumentation. Boom deployment tests in Thermal Vacuum, for example, are best performed at the component level since these devices require special GSE take-up reels, etc. Similarly, devices mounted on the exterior of the probe will see greater thermal profiles in their component tests than possible at the instrument level of assembly. The following table expresses an overall summary of the program testing (*source Concept Study Report*)

Test Description	Component	Instrument
Functional	√	√
Deployment	√	√
Self-Compatibility	-	√
Cleanliness	√	-
EMC/EMI	-	√
DC Mag Field	√	-
AC Mag Field	-	√
ESC	√	-
Vibration	√	-
T/V (Cycles)	√ (2)	√ (6)

2.1 Integration and Test Flow

Figures 2.1-1 through 2.1-10 summarize the Integration and Test Flow for the Instrument Payload Engineering Test Unit (ETU), Flight Instruments, and the Instrument Payload Flight Units. Instruments are integrated one at a time to the Instrument Data Processing Unit (IDPU). Formal EMI/EMC testing is conducted on the ETU system only. Self-capability is completed on the flight system. During Thermal-Vacuum testing, the system will be operated continuously in functional modes with additional tests demonstrating instrument performance and mechanism function. Limited Performance Tests will demonstrate start up capability from a non-operational state at high and low temperature extremes. Instruments are vibration tested prior to Payload integration. Vibration testing after Instrument Payload integration will be conducted only on specific instrument components as required.

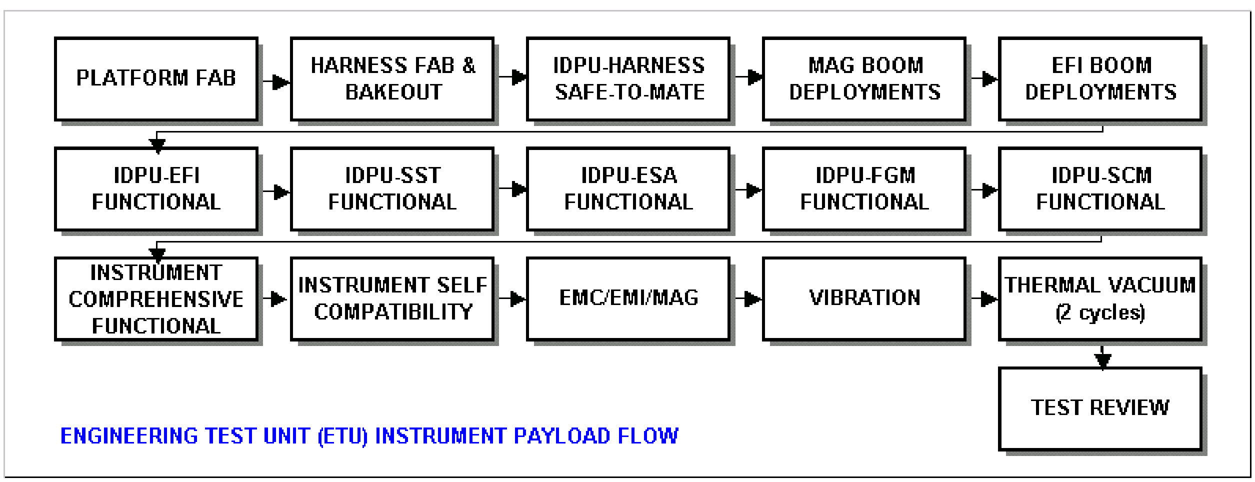

Figure 2.1-1: Instrument Payload ETU Environmental Test Flow

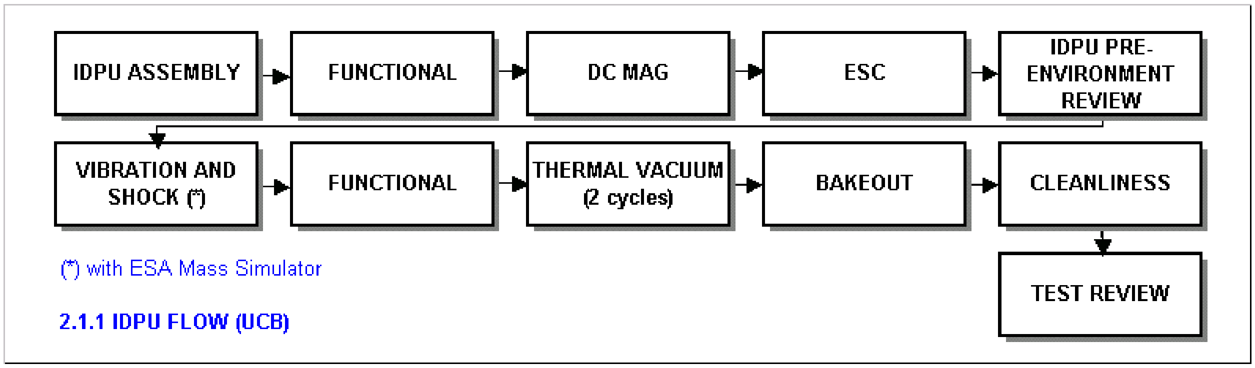

Figure 2.1-2: IDPU Flight Environmental Test Flow

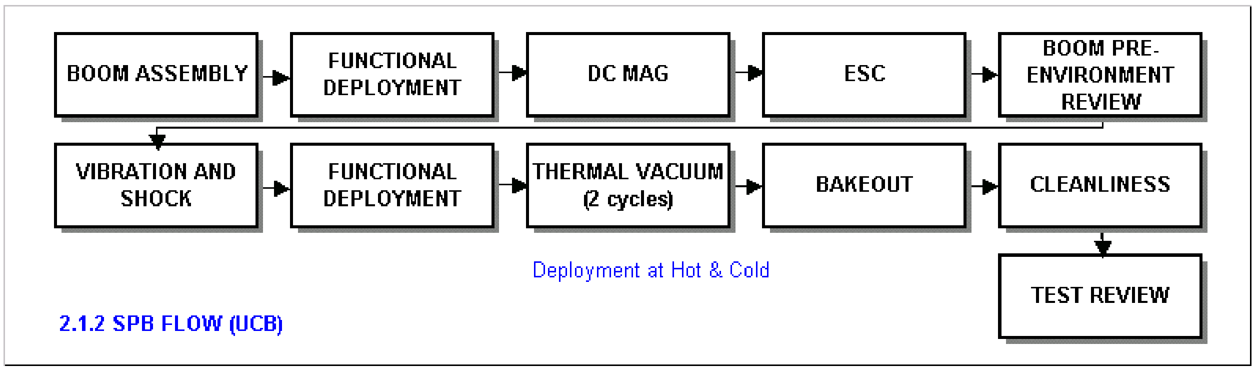

Figure 2.1-3:EFI Spin Plane Boom Environmental Test Flow

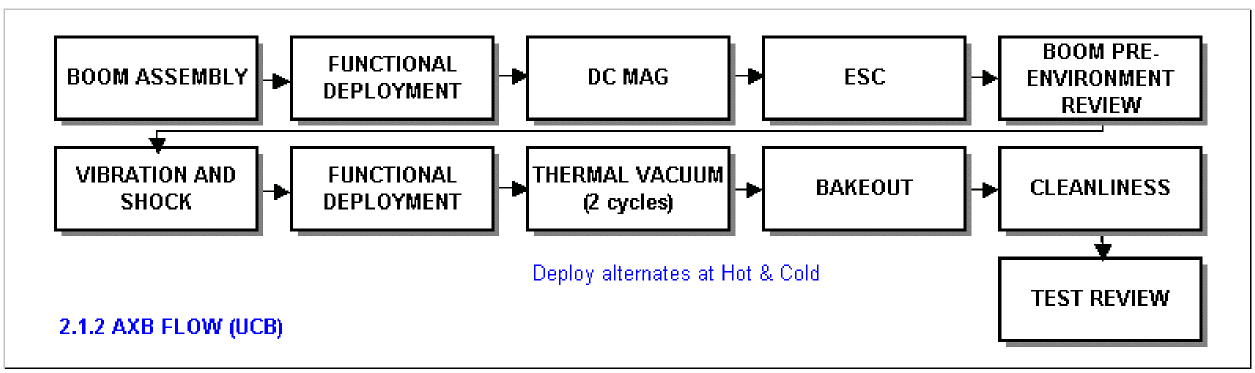

Figure 2.1-4: EFI Axial Booms Environmental Test Flow

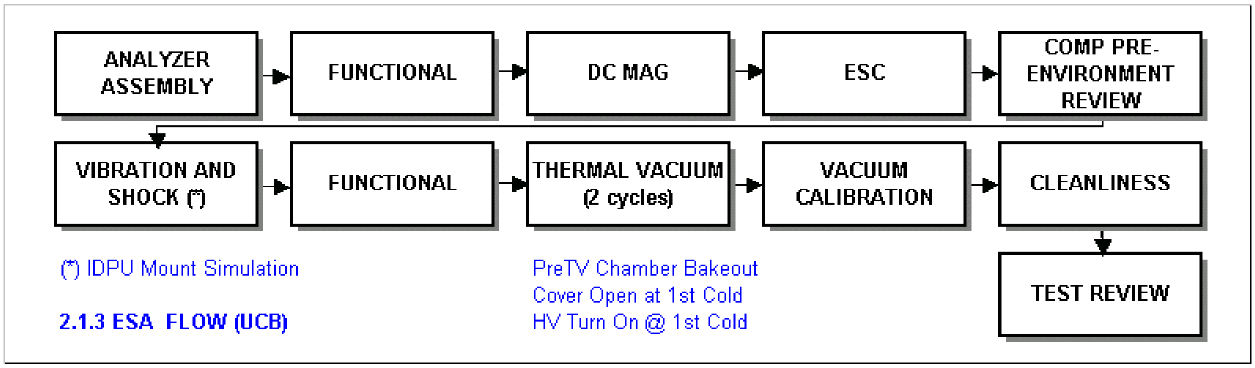

Figure 2.1-5: ESA Environmental Test Flow

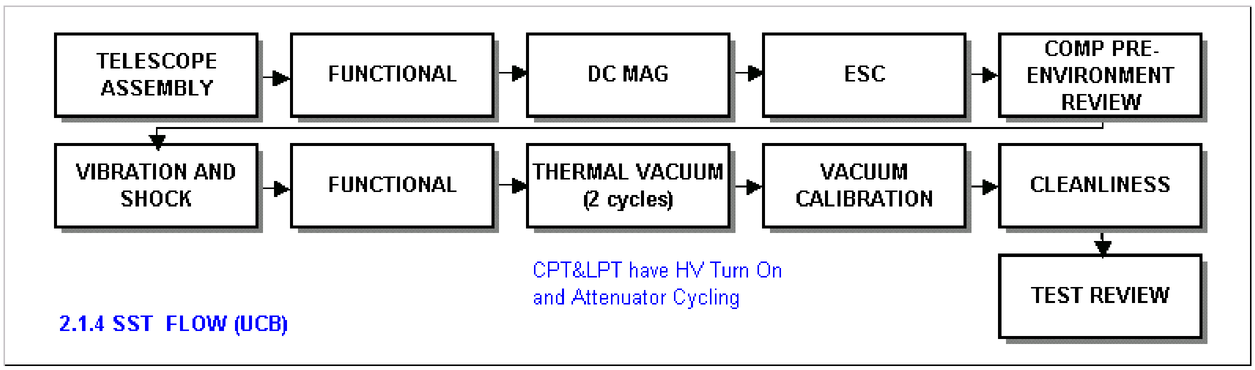

Figure 2.1-6: SST Environmental Test Flow

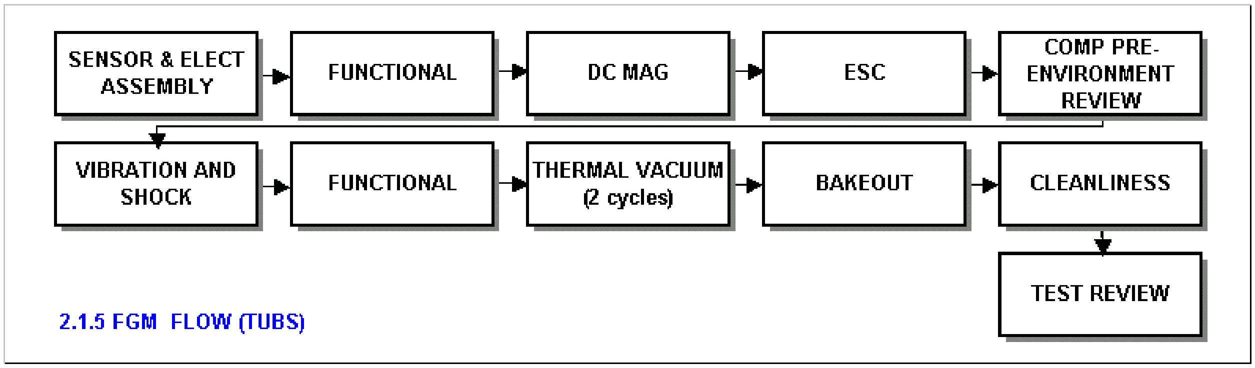

Figure 2.1-7: FGM Environmental Test Flow

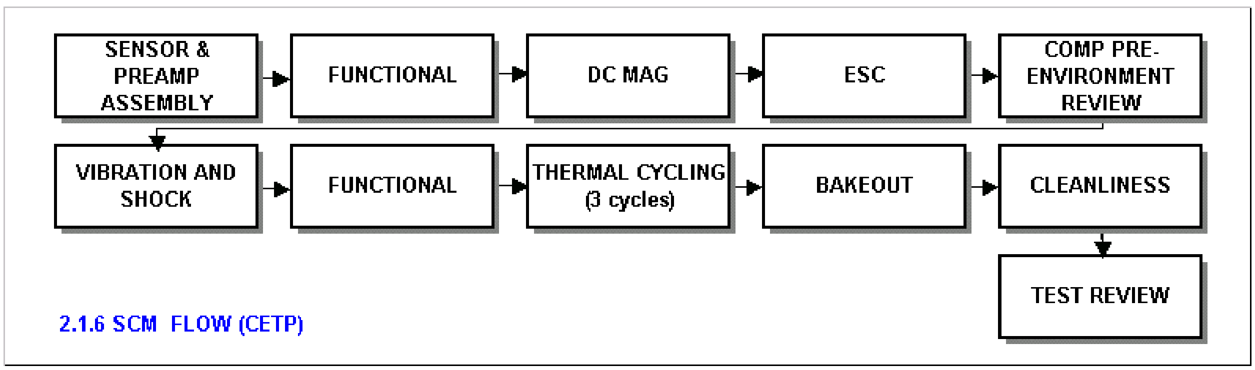

Figure 2.1-8: SCM Environmental Test Flow

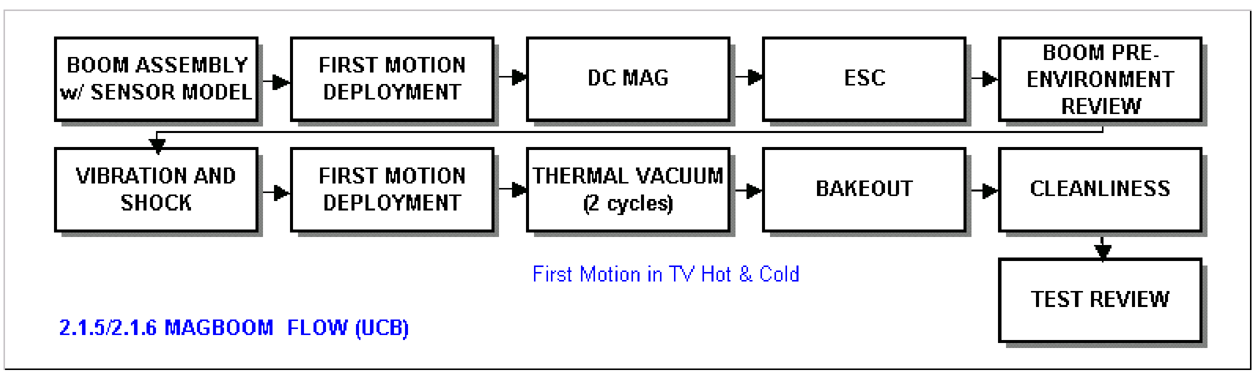

Figure 2.1-9: Magnetometer Booms Environmental Test Flow

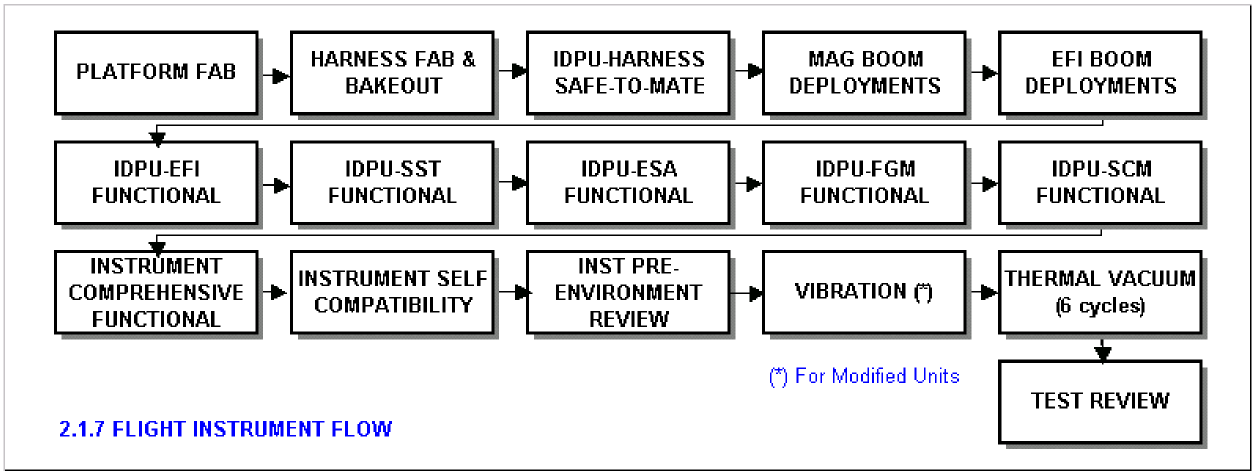

Figure 2.1-10: Flight Instrument Payload Environmental Test Flow

2.1.1 Functional Testing

Instrument components are tested throughout Payload Integration and Test Flow to demonstrate continued compliance with performance requirements and to determine if there is a change in baseline performance. Each Instrument developer shall develop some methodology to assess instrument health after each test so as to find any anomaly as early as possible. The methodology shall be documented in Instrument-specific Comprehensive Performance Tests (CPTs). The CPTs are detailed functional tests conducted under conditions of varying internal and external parameters with emphasis on all possible modes of operation. The CPT includes all instrument commands and modes of operation, to the maximum extent possible. By Instrument Payload integration, the CPT will be an automated test. A CPT for each Instrument shall be conducted immediately after it is integrated; before and after any vibration tests; and before, during (as practical), and after Thermal Vacuum testing. The CPT will be used during all environmental test operations except vibration where it will be executed prior to the test and again afterwards. In addition, Limited Performance Tests (LPT) shall be developed for each Instrument to quickly demonstrate performance periodically during the integration and test flow.

Before integrating any instrument components to the IDPU an Electrical Interface Test (Safe-to-Mate) will be performed on the component interfaces to ensure that the interface levels are within specifications, and that all connecting harnesses are correctly routed.

Prior to Instrument Payload integration, flight instrument calibration will provide additional assurance that each instrument will meet all performance specifications. The accumulated instrument operating time shall be 1000 hours minimum with the last 100 hours being failure free (TBR). This accumulated time includes all bench, EMC, T/V, burn-in and calibration times.

2.1.2 Test Documentation

- Test Procedures: Test Procedures are prepared for any test involving flight hardware. These procedures should be peer reviewed by other members of the instrument team and by the engineer at the facility where the tests are performed. When appropriate, each procedure will identify the item level of assembly, configuration, test objectives, test facilities and instrumentation, operational safety considerations, contamination control requirements as well as a description of the functional operations and personnel responsibilities. All procedures require approval by the QA engineer. Test procedures are referenced in the Verification Matrix and/or the Environmental Test Matrix as applicable.

- Test Reports: Test Reports will be written for all major tests on flight hardware. Test reports on developmental items or engineering units are not required unless they are part of the formal qualification plan. QA tracks all test reports. The test reports are referenced in the Verification Matrix and/or the Environmental Test Matrix as applicable.

- Problem Failure Reports (PFR): Unsatisfactory performance during environmental testing shall be documented using a PFR. Unsatisfactory performance is defined as (1) a performance deviation from the expected or (2) predicted result or a deterioration or change in performance that could prevent the test item from meeting its functional, operational or design requirements as related to the overall system function. The cognizant hardware engineer will inform the QA engineer of the initiation of the PFR. All PFRs are assigned a unique document number and reported via the THEMIS UCB Configuration Control System. The PFR records the failure class level, failure description, notification, problem diagnosis, and problem correction information. The process for initiating, tracking and reporting PFRs is further detailed in *THM-SYS-011 THEMIS Configuration Management Plan*.
- Close-out Activity: Close-out activities include any remedial action taken in response to a PFR. Testing will be repeated to the extent necessary to demonstrate satisfactory performance, and, where necessary, the validity of previously completed tests. The Project Manager and Mission Systems Engineer approve all close-out procedures including redesign or modifications as well as re-testing plans with specific pass/fail criteria.
- Acceptance Data Package: The Acceptance Data Package includes: environmental test reports; test-related PFRs with close-out activity authorization, procedures and report; inspection reports prior to or subsequent to environmental testing; and any waivers relating to the environmental test requirements. Review of the Acceptance Data Package qualifies the Instrument Payload for delivery to the Probe Bus for integration.

3. Mechanical Design and Test

To ensure the structural integrity of the final flight system, instrument component level vibration tests shall be completed prior to instrument payload integration and test. Table 3.1 indicates the structural and mechanical activities to be performed on the flight components. The activities are further described in the following sections.

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Table 3.1: Structural and Mechanical Verification Requirements

Requirement	Level of Assembly	
	Component	Instrument Payload
Stiffness	A, T	-
Strength	A, T1	-
Random Vibration	T	-
Sine Vibration	T	-
Acoustics	A, T1	-
Mechanical Shock	A, T1	-
Pressure Profile	A, T1	-
Mass Properties	T	-
Mechanical Function	T	-
- = No test required A = Analysis required T = Test required T1 = Test required if indicated by analysis or other consideration		

3.1 Stiffness

Large amplitude transients induced by the launch vehicle coupled with the resonance requirements of the Probe structure result in a stiffness requirement for all instrument components. The minimum resonant frequency required is shown below:

Minimum Resonant Frequency	
Components	Stowed > 75 Hz Deployed > 0.25 Hz

Prior to any other dynamics testing, each instrument component shall be subjected to a low-level sine sweep vibration test in each of three mutually perpendicular axes, one of which is normal to the mounting surface. The sine survey shall be performed from 5Hz to 2000Hz at a level of 0.25g to identify all major resonances of each instrument component and verify adherence to the stowed stiffness requirement. For Instrument components mounted on brackets, this test shall be performed with the instrument component mounted to a flight or "flight-like" bracket. The deployed stiffness requirement shall be verified by analysis.

3.2 Strength

All instruments components shall be designed to static-equivalent accelerations at their center-of-mass as shown below:

Design Limit Load for All Components & Instruments	
Weight (lbs)	Load Factor (G)
< 20	40
20-50	31
50-100	22
100-200	17
200-500	13

Strength verification shall be demonstrated by subjecting the item to 1.25 times flight limit loads based on combined quasi-static and dynamic loads during flight on the Delta II 7925-10 launch vehicle.

Test frequencies shall be selected that are low enough to assure rigid body motion of the item under test and still be compatible with the low frequency limitations of the test shaker system (if these conditions cannot be met, alternate means of testing, such as using a centrifuge, shall be considered). The number of sinusoidal dwells, or reversals, made at specified levels during the test shall be 10 plus or minus 5 cycles. The test shall be performed in each of three orthogonal component axes.

Alternatively, component strength verification may be accomplished by analysis that demonstrates that the hardware has positive margins on yield at loads equal to 2.0 times the flight limit load, and positive margins on ultimate at loads equal to 2.6 times the limit load. However, structural elements fabricated from composite materials, ceramics or beryllium, or which include bonded joints, shall not be qualified by analysis alone.

3.3 Random Vibration

Each instrument component shall be subjected to a random vibration test at protoflight or flight acceptance levels. Protoflight levels shall apply to the first (F1) component only. All duplicate items follow-on (F2-F6) components shall be subjected to acceptance levels.

The required test levels are specified below unless refined test levels become available through further detail dynamic analysis. Levels shall be applied in each of three orthogonal axes of the component, one axis being perpendicular to the mounting surface interface. To ensure against over-test, a force limited vibration facility or notching the input spectrum to limit component response may be considered.

For Components Less Than 50 Lbs		
Frequency (Hz)	Qualification ASD (G^2/Hz)	Acceptance ASD (G^2/Hz)
20	0.026	0.013
20-50	+6 dB/Oct	+6 dB/Oct
50-800	0.16	0.08
800-2000	-6 dB/Oct	-6 dB/Oct
2000	0.026	0.013
Overall	14.1 Grms	10.0 Grms
Duration	2 minutes	1 minutes
For components weight greater than 50 lbs, the input level may be scaled down based on weight ratio.		

Following each vibration test, the components shall be functionally tested using a LPT sufficient to determine that the electronics are functional, and inspected to verify that no damage has occurred. Prior to and upon completion of all vibration test sequence, the component shall be functionally tested using a CPT.

3.4 Sine Vibration

Each instrument component shall be subjected to a sine vibration test at protoflight or flight acceptance levels. Protoflight levels shall apply to the first (F1) component only. All duplicate items follow-on (F2-F6) components shall be subjected to acceptance levels.

The required test levels are specified below unless refined test levels become available through further detail dynamic analysis. Those levels shall be applied in each of three orthogonal axes of the component, one axis being perpendicular to the mounting surface interface. The sine test shall consist of one upsweep at 4 octaves/min in each of three orthogonal axes at the indicated levels. The method of limiting the component response levels during this test so the maximum expected levels predicted by the Swales coupling analysis are not exceeded is TBD.

Protoflight Sinusoidal Vibration Level For S/C			
Axis	Frequency (Hz)	Level	Sweep Rate
Thrust	5 to 7.4 7.4 to 100	0.5" Double Amplitude 1.4 G	4 octaves/min
Lateral	5 to 6.2 6.2 to 100	0.5" Double Amplitude 1.0 G	4 octaves/min
* Notch CG responses not to exceeded 1.25 times design limit load.			

Sinusoidal Vibration Level For Probe And Components				
Test	Axis	Frequency (Hz)	Level	Sweep Rate
Qualification	X, Y, Z	5 to 16 16 to 100	0.5" Double Amplitude 8.0 G	2 octaves/min
Protoflight	X, Y, Z	5 to 16 16 to 100	0.5" Double Amplitude 8.0 G	4 octaves/min
Acceptance	X, Y, Z	5 to 16 16 to 100	0.5" Double Amplitude 6.4 G	4 octaves/min
* Notch CG responses not to exceeded 1.25 times design limit load.				

3.5 Acoustic

Instruments shall show by analysis that they will survive the acoustic loads experienced during launch. Expected acoustic loads are shown in *THEMIS Environmental Design Specification*.

3.6 Shock

All instruments shall be capable of full operational performance after exposure to the shock environment due to the pyro actuation of probe separation as described below. No attenuation of the shock levels internal to the probe should be used in the design of instrument and components. The shock introduced by the payload separation may not (TBR) require any special tests for instrument qualification.

Table 3.6.1 Shock Level		
Frequency (Hz)	Qualification	Acceptance
100	40G	30G
100-3000	+6.92 dB/Oct	+6.8 dB/Oct
3000-10000	2000G	1400G
Shock test at component level is not mandatory. However, it is vendor's responsibility to ensure their product can survive the specified shock environment.		

Probe A (with Instrument Payload) will be subjected to a separation shock test while attached to a flight-type interface simulator with a flight-type separation clamp band system. The clamp band shall be installed with the specified pre-load tension level. Two firings/separations are required. For flight Probes B-E, one firing/separation is required.

3.7 Pressure and Pressure Change

A venting analysis shall be performed for all flight instrument components susceptible to pressure loadings to verify that positive structural strength margins exist at loads equal to twice those induced by the maximum pressure differential during launch. This requirement also applies to thermal blankets, contamination enclosures and other items susceptible to such pressure loadings. Relief ports on instrument cavities must be designed to accommodate the maximum pressure change associate with ascent after launch. The Delta 7925-10 payload fairing internal pressure environment as the vehicle ascends through the atmosphere is shown below. The figure presents expected extremes of internal pressure during ascent. The maximum rate of change of pressure(p) is -0.6 psi/sec.

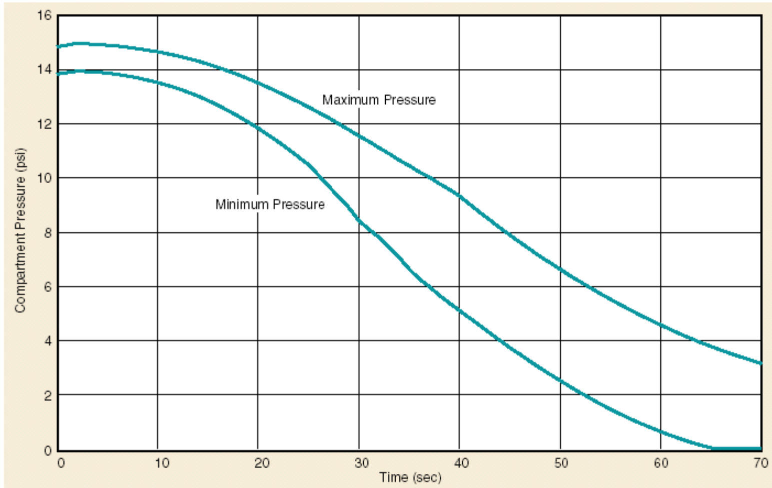


Figure 4-6. Delta II Payload Fairing Compartment Absolute Pressure Envelope

UCB will determine if there is a need for a pressure profile test by analysis. A test will be required if the analysis does not indicate positive margin at loads equal to twice those induced by the maximum pressure differential during launch. It is not expected that a test will be required. If a test is required it will be performed as indicated in GEVS-SE.

Fracture control and proof pressure test requirements of EWR 127-1 Eastern and Western Range Safety Requirements shall apply to pressure vessels, lines and fittings. Required qualification and proof pressure tests will be performed on all Instrument flight hardware if required per EWR 127-1.

3.8 Mass Properties

Measurement of the weight and center of gravity of each instrument component shall be made to show compliance with specified requirements and provide accurate data for the mass properties control program. The required mass properties to be measured will include at a minimum the mass, center of gravity and moments of inertia for each instrument component

3.9 Mechanical Function

A functional life test shall be performed for mechanical or electromechanical elements that move repetitively as part of their normal function. The test spectrum for the life test shall represent the required mission life for the flight item, including both ground and on-orbit operations. The minimum requirement for demonstrated life test operation without failure shall be 10 times the number of mechanical functions during the mission life, unless the part is on the Limited Life Items list. The life test item must be similar to the actual flight mechanism, particularly with respect to detailed assembly procedures and certification logs. All functional life tests shall be performed in ambient conditions.

4. Thermal Design and Verification

UCB will perform a series of thermal and thermal/vacuum tests and analyses to demonstrate that the Instrument Payload will perform satisfactory in space, and that the thermal design will keep the instrument components within limits. The thermal design shall be verified by comparing predicted and actual temperatures at the base-plate interface. Thermal-Vacuum tests will be performed in-house at UCB/SSL. The vacuum chamber contains the equipment necessary to perform high temperature bake-outs, thermal vacuum tests, thermal cycle tests and thermal balance tests. Table 4-1 summarizes the tests and analyses that will be performed.

Table 4.1: Vacuum and Thermal Verification Requirements

Requirement	Level of Assembly	
	Component	Instrument Payload
Thermal Cycles (Ambient)	T	-
Thermal Vacuum	T	T
Burn-In	T	T
Bake-Out	T	T
Thermal Balance	-	A, T1
- = No test required A = Analysis required T = Test required T1 = Test required if indicated by analysis or other consideration		

4.1 Thermal Cycles

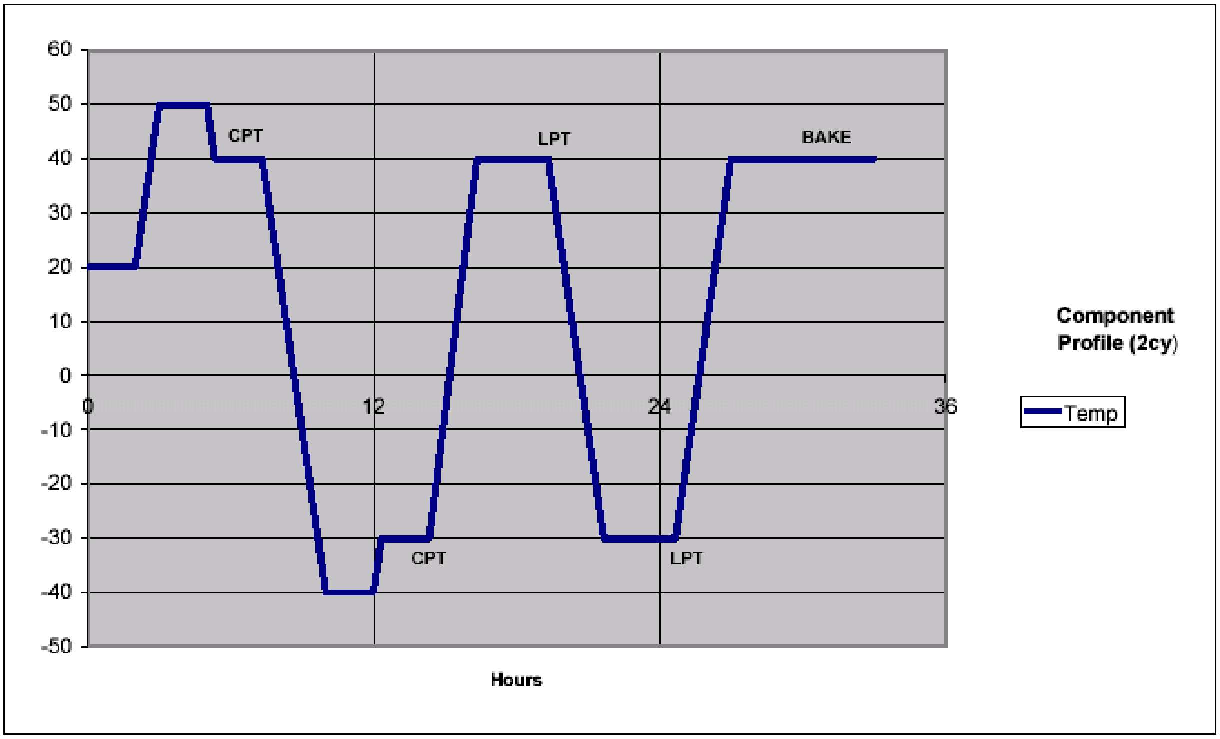
Ambient thermal cycles shall be completed on Instrument ETUs prior to flight build (TBD).

4.2 Thermal Vacuum Testing

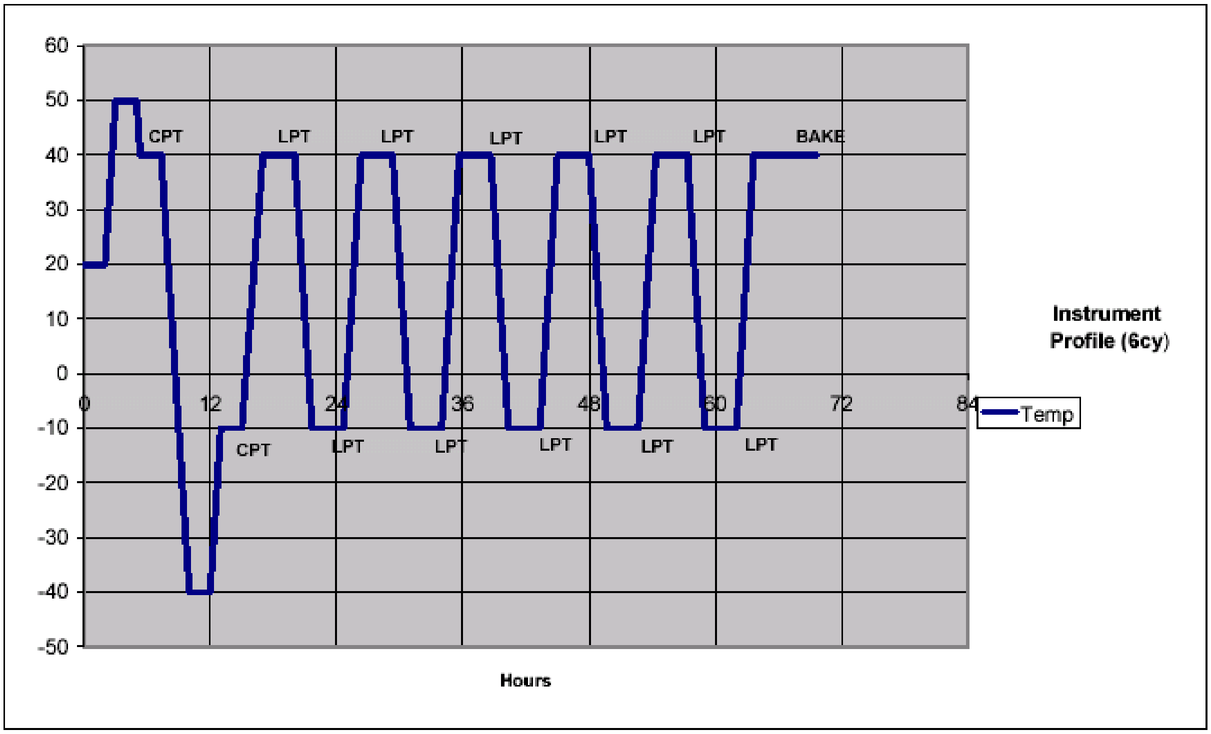
Thermal vacuum testing of flight instrument components shall be performed to demonstrate that the component will perform satisfactorily in vacuum at temperatures 10C beyond the component operating limits and during transitions. In addition, the component shall be soaked for at least 1 hour at 10C beyond the non-op limit with the power removed. The component shall then be powered to verify turn-on capabilities at these temperatures. Operating and Non-op limits for all instrument components are shown below:

Operational	**OP LIMITS**		**ECLIPSE OP LIMITS**		**NON-OP LIMITS**	
Unit	Cold	Hot	Cold	Hot	Cold	Hot
IDPU	-30	40	-50	40	-50	65
SST Sensor	-55	40	-65	40	-65	65
ESA	-30	40	-50	40	-50	65
EFI SPB	-20	40	-50	40	-50	65
EFI AXB	-20	40	-50	40	-50	65
SCM Boom	-20	40	-75	65	-50	65
SCM Sensor	-50	65	-100	80	-100	80
SCM Preamp	-100	40	-50	40	-50	80
FGM Boom	-50	65	-75	65	-50	65
FGM Sensor	-80	80	-100	80	-100	120
INST	-20	40	-50	40	-50	65

Testing of each instrument component shall be subjected to a minimum of 2 temperature cycles prior to delivery to Instrument Payload integration, and 6 temperature cycles will be completed on the integrated Instrument Payload. At least 4 cycles will be completed on the integrated Probe. The test duration shall be based on the time required to perform performance/functional testing of the component at each hot and cold temperature plateau but, as a minimum, two-hour soak periods shall be conducted. ESA and SST will have extended first cycle hot dwells to reduce the chamber contamination levels. During cycling the instrument component should be operating and monitored with a CPT being run at each extreme. Each TV ends with a Bakeout phase in which contamination verification is performed. Chamber backfill is performed with high grade GN2 (LN2 boiloff). A representative thermal vacuum cycle is shown in Figure 4.2-1 below.



4.2-1 Representative Component Thermal Vacuum Sequence



4.2-2 Representative Instrument Payload Thermal Vacuum Sequence

For components that are determined by analysis to be insensitive to vacuum effects relative to temperature levels and temperature gradients, the test requirements may be satisfied by temperature cycling at normal room pressure in an air or gaseous-nitrogen environment. If this approach is used, the cycling at ambient pressure shall be increased (both the temperature range and the number of cycles) to account for uncertainties. The qualification margin of ±10°C (in vacuum) shall be increased to ±15°C if testing at ambient pressure is performed. Likewise, the number of thermal cycles shall be increased by 50 percent if testing at ambient pressure (e.g., from 4 cycles in vacuum to 6 cycles at ambient pressure). Project approval is required if testing at ambient pressure is implemented.

Boom Deployment:

Thermal Vacuum testing shall be performed on the flight boom units at UCB to demonstrate that the mechanism will deploy satisfactorily in vacuum at temperatures 10C beyond the temperature predictions. Deployment tests shall occur at both hot and cold extremes. In addition, the testing shall demonstrate the ability of the boom mechanism to perform correctly after being exposed to temperatures 10C beyond the specified non-functional extremes. The EFI Spin Plane Booms shall demonstrate a full deploy with take-up reel. The EFI Axial and Magnetometer Booms shall demonstrate a first motion deploy at hot and cold.

4.3 Burn-In Testing

Burn-in Testing will be accomplished at to detect defects which can occur during early electronic component life. Instrument component burn-in shall be done at a temperature 10C beyond the upper predicted mission extreme. Instrument components shall be monitored during the burn-in process by conducting periodic CPTs.

4.4 Bake-out

Bakeouts are planned as part of the overall contamination control program in order to remove volatile materials from the flight instrumentation. All separable harnesses and blankets will be baked out at 100C for 24 hrs. Component and Instrument level TV tests will end with a bakeout phase to verify contamination compliance.

4.5 Thermal Balance

Thermal balance analyses will be performed by UCB to demonstrate that the instrument thermal design will maintain the hardware within established thermal limits. Thermal Balance Test will be performed at the Probe Level.

5. Electromagnetic Compatibility

UCB will perform EMC/EMI/MAG verification tests to demonstrate that the instrument payload will meet the EMC requirements of the project. LPT tests shall be performed prior to and after EMC testing and during testing as appropriate. EMI/EMC testing on the THEMIS ETU Instrument Payload will be performed at EMCE Engineering, Inc. in Fremont, California.

5.1 Test Levels and Configuration

Conducted emission tests (Methods CE01, CE03 and CE07) will be performed per MIL-STD-462 procedures on the 28V power line. The tests will be carried out with the Instrument Payload in nominal science mode.

Conducted susceptibility tests (Methods CS01, CS02 and CS06 modified) will be performed per MIL-STD-462 procedures on the 28V power line at a test voltage of 21V DC. The tests will be carried out with the Instrument Payload in nominal science mode.

Radiated emissions and susceptibility are not applicable (TBD) at the Instrument Payload Level. These tests will be done at the Probe level.

The Instrument Payload will be mounted on a common ground plane, which is referenced to the ground plane in the main shielded enclosure. DC power will be supplied from an adjacent shielded enclosure via a metallic tube, which is interconnected between the two chambers. The EMC equipment will be contained in a third shielded container. All cables will be configured in a manner as similar as practical to the flight harness.

5.2 Test Instrumentation and Data

All measurements will be made in accordance to MIL-STD-462 procedures. The tests will be conducted by qualified EMCE Engineering personnel using test equipment (spectrum analyzer, current probe, etc.) maintained in a current state of calibration. After completion of the tests, data will be reviewed and compared with the limits stated above. EMCE will provide UCB with a Certification of Compliance Report.

Electromagnetic Compatibility Requirements

Description	MIL-STD-461C Requirements	MIL-STD-461C Test Method	Test Limits
Conducted Emissions, DC Power Leads (30 Hz to 15 KHz)	CE01	Part 3, Para 2.2.1, DC Power Leads	Figure C9-1 NB
Conducted Emissions, DC Power Leads, 0.015 to 50 MHz	CE03	Part 3, Para 3.2.1, DC Power Leads	Figure C9-1 NB Figure C9-2 BB
Conducted Emissions, Antenna Terminals, 10 KHz to 100 GHz	CE06	Part 3, Para 4.2.1 S-band. Part 3, Para 4.2.2 S & K-band	Para 4.2.1a & b NB Para 4.2.2a & b BB
Conducted Emissions, Single Event Switching Transients, DC Power Leads	CE07	Part 3, Para 5.2b, DC Power Leads	+50%, -150% of 28 VDC for spike duration of < 50µS
Conducted Susceptibility, DC Power Leads, 30 Hz to 50 KHz	CS01	Part 3, Para 6.2, DC Power Leads, modulation requirements for Test Plan	2.8 V RMS or 50 watts
Conducted Susceptibility, DC Power Leads, 50 KHz to 400MHz	CS02	Part 3, Para 7.2, DC Power Leads, modulation requirements per test plan	1V RMS or 1 watt
Intermodulation, 15 KHz to 18 GHz, S-band only	CS03	Part 3, Para 8.1	52 dB
Conducted Susceptibility, Spikes, Power Leads	CS06	Part 3, Para 11.2, DC Power Leads, 10 µsec	+28 VDC for 10µS, -28 VDC for 10µS
Rejection of undesired signals, 30 Hz to 18 GHz, S-band only	CS04	Part 3, Para 9.1	Table 3-4
Cross Modulation, 30 Hz to 18 GHz, S-band only	CS05	Part 3, Para 10.2	50 dB
Radiated Emissions, Magnetic Field, 30 Hz to 50 KHz	RE01	Part 3, Para 13.1	Figure C9-5
Radiated Emissions, Electric Field, 14 KHz to 18 GHz	RE02	Part 3, Para 14.1	Figure C9-3 NB* Figure C9 BB*
Radiated Susceptibility, Electric Field, 14 KHz to 40 GHz	RS03	Part 3, Para 17.1, modulation requirements 1 KHz	14 KHz -2 GHz 2V/M 2 GHz -3 GHz 20V/M 3.6GHz-8 GHz 2V/M 8 -9 GHz 50V/M 9 -18 GHz 2V/M

- **The limit shall be reduced in accordance with the S-band receiver sensitivity.**
- **Radiated tests (RE and RS) are completed at the probe level only.**

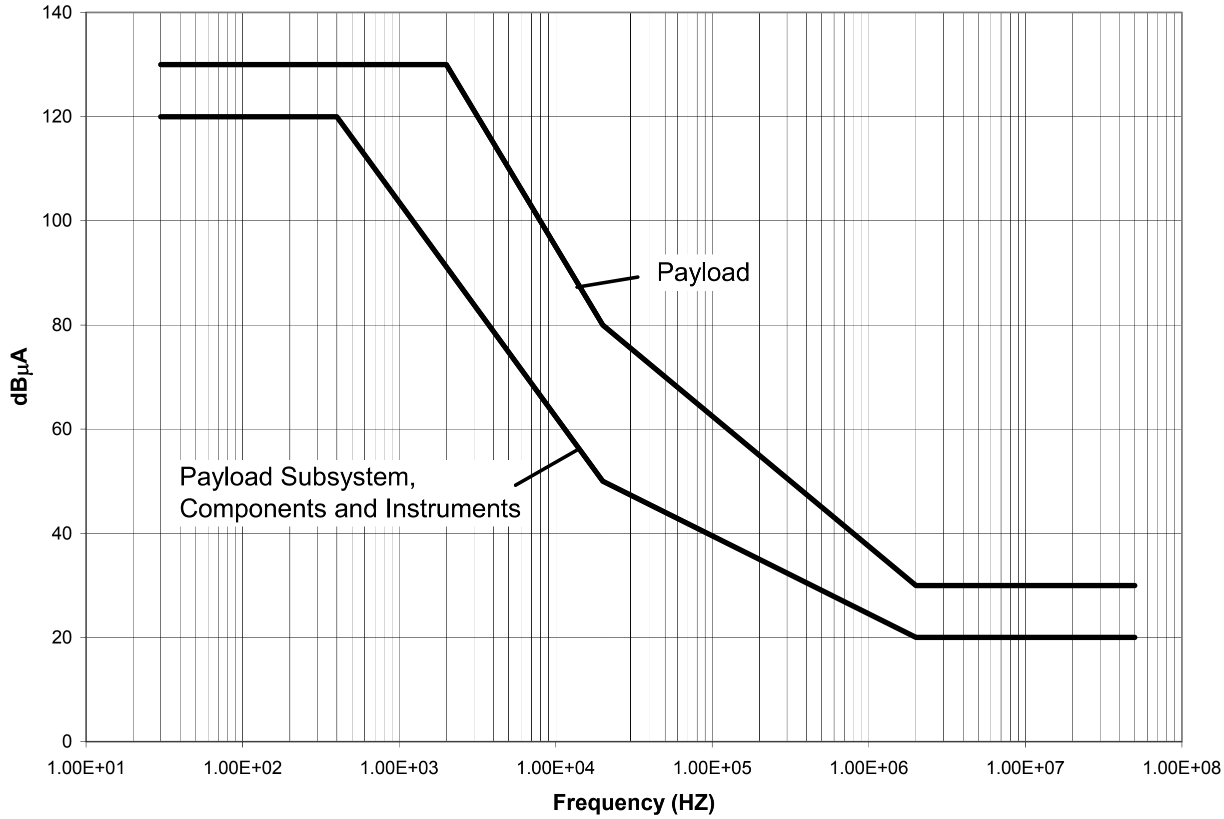
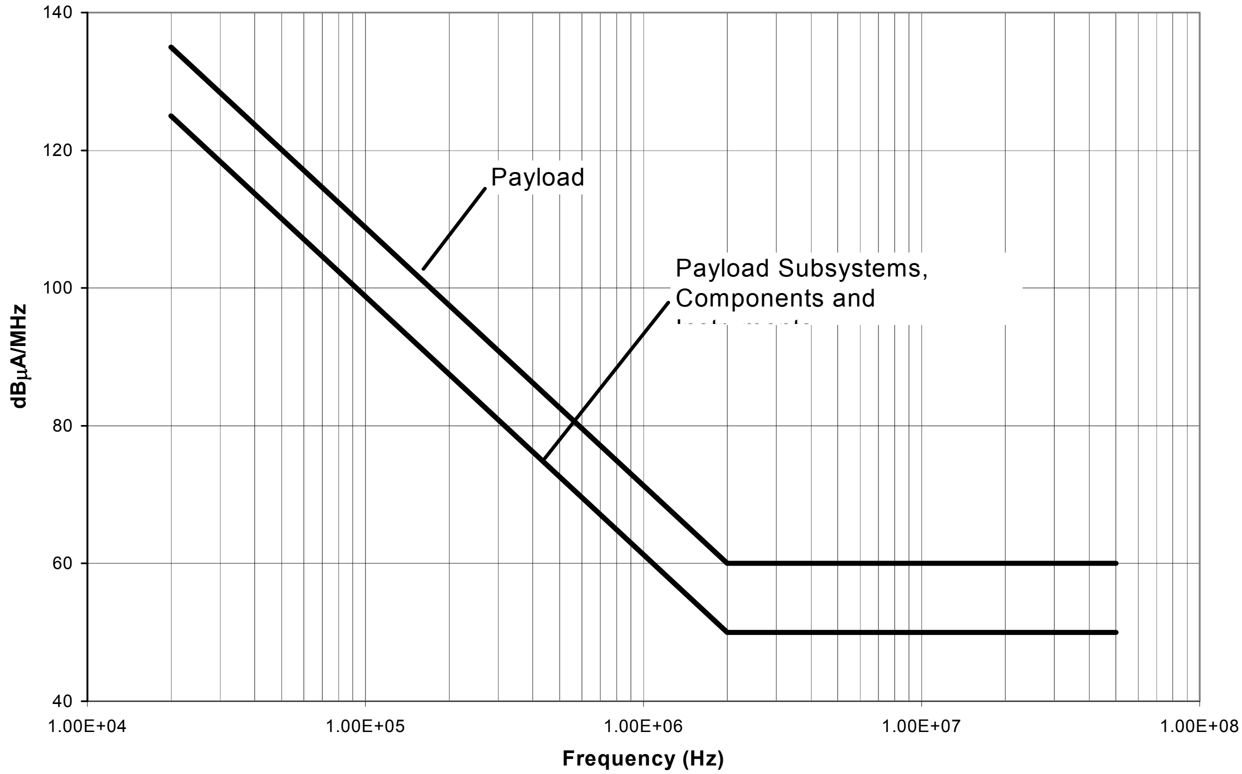


Figure C9-1 Narrowband Conducted Emissions Limits (CE01, CE03)



Broadband Conducted Emissions Limits (CE03)

Table C9-1 Spurious Signal Rejection (CS04)

Description	Specification Limit
Spurious Signal Rejection	Reference > 60 dB (without diplexer)
	Image > 60 dB
	221 F1 + 5 MHz > 80 dB
	221 F1 -5 MHz > 80 dB
	Fo + 1/2 1st IF > 50 dB
	Fo -1/2 1st IF > 50 dB
	Fo + 1/4 1st IF > 50 dB
	Fo -1/4 1st IF > 50 dB
	Fo +1/2 2nd IF > 50 dB
	Fo -1/2 2nd IF > 50 dB
	Fo +2nd IF >50 dB
	Fo -2nd IF > 50 dB

6. Contamination

In accordance with the *THEMIS Contamination Plan*, the Instrument Payload will be certified for cleanliness at UCB prior to delivery to Swales. Certification measurements will be made per UCB Cleanliness Guidelines and Contamination Control procedures. Cleanliness levels are verified by making TQCM measurements during the Instrument Payload bake-out. To ensure the system passes the final system TQCM certification, unit level certification after dedicated contamination bake-outs will be done as necessary.

Specifically, to verify that the hardware meets the outgassing requirements, UCB will use the following approach:

1. All flight hardware will be precision cleaned.
2. All non-metallic materials will be baked at the temperature and times listed in Thermal Bake-out Section above.
3. The thermal vacuum chamber will be cleaned prior to TQCM certification to reduce the background to approximately 15 Hz/hr (TBR). Certification on the entire Instrument Payload will be done after the system has been vacuum baked for at least 48 hours. The TQCM will be at -20 degrees C and all hardware will be at 40 degrees C. The TQCM will generally view the center of the chamber volume. The TQCM frequency will be logged at least every hour for approximately 8 hours.

7. Magnetics

The instrument materials and component parts will be selected for their low magnetic properties. All questionable materials will be tested prior to inclusion in the instrument components.

DC magnetic measurements of each instrument component will be made after assembly, and AC measurements made at the spacecraft level in a magnetic facility.