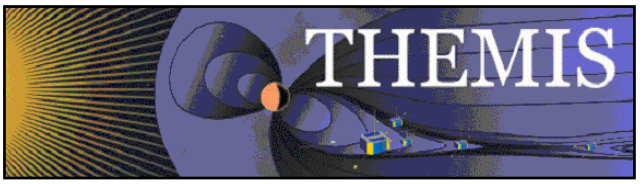

THEMIS Mission
Contamination Control Plan

THM-SYS-004
Revision A

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Document Revision Record

Rev.	Date	Description of Change	Approved By
-	10/22/03	Preliminary Draft	-
A	6/4/04	Updates from Swales and GSFC	Taylor

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TBDs

Identifier	Description
TBD1	QCM Hz/hr

1. OVERVIEW

THEMIS is a NASA Explorer mission which will launch a constellation of five micro-satellites in mid-2006. Flying in synchronous orbits within the earth's magnetosphere, the satellites will measure the particle processes responsible for eruptions of the aurora. As the prime contractor for THEMIS, the University of California at Berkeley will provide the systems engineering, flight instrumentation, ground-based imagers, mission operations, and Performance Assurance. Swales Aerospace will provide spacecraft buses. Key international partners include teams from Canada, France, Germany, and Austria.

As a PI mode mission, the Explorer's Office is responsible for oversight of UCB in the proper development of the spacecraft and ground systems. The Explorer's Office is responsible for arranging a suitable Launch Vehicle and launch site support through KSC. These efforts are coordinated by the Mission Manager.

UCB will provide a Project Office which contains at least the following roles and responsibilities: Project Manager (PM), Mission Systems Engineer (MSE), Lead Mechanical Engineer (LME), Mission Assurance Manager (MAM), Financial Manager (FM), and Contracting Officer (CO). In this document, unless otherwise stated, the term Project refers to the THEMIS Project office at UCB, and the terms GSFC and EO refer to the GSFC Explorers Office.

1.1 PURPOSE

The purpose of this document is to define the contamination requirements for THEMIS from fabrication through launch and to outline methods to ensure these requirements are satisfied.

1.2 OBJECTIVES

The objectives of the THEMIS Contamination Requirements and Control Plan are as follows:

- Define the contamination requirements for THEMIS.
- Identify contamination sources for THEMIS.
- Establish contamination controls for each phase of THEMIS development to maintain required cleanliness levels.
- Establish a cleaning schedule for THEMIS hardware.
- Establish a plan for cleanliness monitoring and verification.
- Establish overall responsibility for executing provisions of this plan.

1.3 *RESPONSIBILITY*

Each organization providing flight hardware for the THEMIS mission is responsible for complying with the provisions of this plan, and the applicable detailed plans and procedures referenced herein. The THEMIS Probe and Probe Carrier Contamination Control Plan (CCP) will further address the contamination control undertaken by Swales during the probe design, fabrication, test and launch processing phases.

2. APPLICABLE DOCUMENTATION

The following documents are applicable to the extent specified herein. In the event of a conflict, the requirements of this document shall govern.

2.1 PROJECT DOCUMENTS

GSFC-410-MIDEX-001C	MIDEX Performance Assurance Guidelines
GSFC-410-MIDEX-003A	MIDEX Safety, Reliability and Quality Assurance Requirements
THM_PA_000A	THEMIS Performance Assurance Requirements
THM_PA_001A	THEMIS Performance Assurance Implementation Plan
THM_PA_002	THEMIS FGM PAIP
THM_PA_003	THEMIS SCM PAIP
THM_PA_004	THEMIS Probe and Probe Carrier PAIP
SAI_PLAN_0656	THEMIS Probe and Probe Carrier CCP
tbd	THEMIS Probe Cleaning and Verification Procedure
tbd	THEMIS Clean Area and Personnel Operations Proc
tbd	THEMIS Subsystems Bakeout Plan
tbd	THEMIS Instrument Purge Plan

2.2 *REFERENCE DOCUMENTS*

a. FED-STD-209D	Clean Room and Work Station Requirements, Controlled Environment
b. MIL-STD-1246B	Product Cleanliness Levels and Contamination Control Program
c. NASA-JSC-SP-R-0022A	Specification Vacuum Stability Requirements of Polymeric Material for Spacecraft Application
d. NASA-JSC-SN-C-005	Specification Contamination Control Requirements for the Space Shuttle Program,

	Revision C
e. NASA-RP-1124-87	Outgassing Data for Selected Spacecraft Materials
f. GSFC-TLS-PR-7324-01	Contamination Control Procedure for the Tape Lift Sampling of Surfaces
g. GSFC-MLS-PR-7324-01	Contamination Control Procedures for the Molecular Wipe Sampling of Surfaces

3. ACRONYMS & TERMINOLOGY

3.1 ACRONYMS

EFI	Electric Field Instrument
ESA	Electron Electrostatic Analyzer
ESD	Electrostatic Discharge
FGM	Fluxgate Magnetometer
GSFC	Goddard Space Flight Center
I&T	Integration and Test
IPA	Isopropyl Alcohol
ITO	Indium Tin Oxide
MAM	Mission Assurance Manager
MLI	Multi Layer Insulation
NASA	National Aeronautics and Space Administration
NVR	Non-Volatile Residue
PM	Project Manager
QCM	Quartz Crystal Microbalance
SCM	Search Coil Magnetometer
UCB	University of California, Berkeley
UCLA	University of California, Los Angeles

3.2 TERMINOLOGY

a. Clean Area	Area where airborne particulate contamination levels are strictly controlled.
b. Contamination	Unwanted material causing degradation in the desired function of an instrument or flight hardware.
c. Contamination Control	Organized action to control contamination levels.

d. Fiber	Particle whose length-to-width ratio exceeds 10:1, with a minimum length of 100 microns.
e. Gross Cleaning	Cleaning hardware surfaces in a normal work area to visual inspection standards.
f. Nitrogen Purge	Pressurized flow of clean, dry nitrogen through a system to displace impurities and reactive species.
g. Non-Volatile Residue	Soluble material causing degradation in the desired function of an instrument or flight hardware.
h. Particle	Small quantity of solid or liquid material with definable shape or mass and a length-to-width ratio less than or equal to 10:1.
i. Particle Size	Expressed as the apparent maximum linear dimension or diameter of the particle.
j. Precision Cleaning	Cleaning procedure done in a controlled environment to attain a specific level of cleanliness. This procedure follows gross cleaning.
k. Sensitive Surfaces	Flight hardware surface requiring a specific cleanliness level to meet minimum performance levels.
i. Solvent Flushing	Pressurized stream of filtered solvent directed against a surface to dislodge and rinse away contaminating material.
m. Solvent Washes	Quantitative method of verifying MIL-STD-1246B NVR levels by measuring molecular contamination in a solvent washed over a surface.
n. Surface Cleanliness Level	Established level of maximum allowable particulate and/or NVR contamination ranging from visibly clean to specific MIL-STD-1246B levels (e.g., level 500B. See Figures 1 and 2).

o. Swab Sample	Qualitative method of identifying contaminants by analyzing residue on a solvent-soaked swab that was wiped over a surface.
p. Tape Lifts	Quantitative method of verifying MIL-STD-1246B particulate cleanliness levels by measuring particulate contamination on a tape sample that has contacted a surface.
q. Vapor Degrease	Item to be cleaned is exposed to heated solvent vapors that condense on the part and wash away contaminants. (NOTE: Halogenated solvents used to vapor degrease plastics are often outgassed or leached out later. Therefore, if halogenated solvents are used to vapor degrease plastics, a bakeout must follow.)
r. Visibly Clean	Clean surface as seen without optical aids (except corrected vision) when measured by a specific method. For this project, surfaces should be tested from a distance of 6 to 18 inches using a white light ≥100 ft. candles of power as per NASA-JSC-SN-C-0005 Revision C.

4. CONTAMINATION SOURCES FOR THEMIS

To adequately protect THEMIS from contamination and more effectively clean contaminated components, it is essential to identify and understand the possible sources of contamination. These sources will differ at various stages of hardware development for THEMIS.

Table 4.1 presents a summary of contamination sources that could adversely affect THEMIS. This Contamination Plan is designed to minimize the effect of contamination sources and to maintain a cleanliness level which keeps the spacecraft within its contamination budget allocation during all phases.

TABLE 4.1. CONTAMINATION SOURCES FOR THEMIS

Mission Phase	Molecular	Particulate
Fabrication	machining oils, fingerprints, air fallout	air fallout, personnel, soldering, drilling, bagging material
Assembly and Integration	air fallout, outgassing, personnel, cleaning, solvents, soldering, lubricants, bagging material	air fallout, personnel, soldering, drilling, bagging material
Test	air fallout, outgassing. personnel, test facilities, purges	air fallout, personnel, test facilities, purges, redistribution
Storage	bagging material, purges, containers	bagging material, containers, purges
Transport	bagging material, containers, purges	bagging material, containers, vibration,
Launch Site	bagging material, air fallout, outgassing, personnel, purges	bagging material, air fallout, personnel, checkout activities, other payload activities
Launch	outgassing, venting	vibration and/or redistribution
On Orbit	outgassing, atomic oxygen, probe molecular cloud, thruster plume	micrometeoroid and debris impingement

5. OVERALL CONTAMINATION CONTROL REQUIREMENTS

This section reviews the allowable contamination requirements set for the THEMIS instrument and subsystems based on mission performance goals.

Surface cleanliness levels are specified in accordance with MIL-STD-1246B or NASA-JSC-SN-C-0005. MIL-STD-1246B defines quantitative surface cleanliness levels for particulate and NVR levels. The particulate level is denoted by a numeric value (i.e. 100, 200,...) and NVR levels are denoted by an alphabetic value (i.e. A, B,...). The quantity of contamination associated with each level is displayed in Figures 1 and 2. NASA-JSC-SN-C-0005, Revision C, defines levels of cleanliness which can be verified by visual inspection with a white lamp. For this mission, surfaces designated as visibly clean will be inspected at a distance

of 2-4 feet using illumination with greater than 50 ft- candles of power (Visibly Clean Sensitive). NASA-JSC-SN-C-0005 levels are illustrated in Figure 2.

Note that the surface cleanliness requirements presented in this section should be met prior to the last possible access point. For external spacecraft surfaces, this will be at the launch site. For internal surfaces, this will be during fabrication or integration.

5.1 THEMIS INSTRUMENT

The THEMIS instrument consists of one ESA assembly, two SST assemblies, six electric field booms, two magnetometer booms, and an electronics box. Upon delivery to Swales, all instrument surfaces will meet a cleanliness level of 500A per MIL-STD-1246B. Following delivery, sensitive components will be maintained at or near Level 500A through the use of protective covers, while less sensitive components will be maintained at a Visibly Clean, Highly Sensitive level per NASA-JSC-SN-C-0005.

The most contamination sensitive components in the THEMIS instrument are found in the ESA and SST assemblies. MicroChannel plates found in ESA and detectors in the SST are subject to degradation if exposed to very small amounts of particulates, hydrocarbons, or humidity. "Gold-Black" surfaces in the ESA are relatively insensitive to contamination, but must be kept contamination free due to very limited cleanability.

Component	Sensitivity Level
ESA	Molecular <0.01 mg/cm^2
SST	Molecular <0.1 mg/cm^2

During typical integration and test operations, the sensitive components in ESA and SST will be purged with Ultra High Purity GN_2 and sealed by cover mechanisms. ESA and SST will be purged at all possible times, unless prohibited by test activities. Details may be found in the Instrument Purge Plan. Instrument providers will be responsible for all purge GSE and implementation.

Table a
Derivation of Cleanliness Levels

Cleanliness Level	Range Surface and Fluids	Quantity of Particulates
1	1	1
5	1 2 5	3 2 1
10	5	3
25	5 15 25	23 3 1
50	5 15 25 50	165 25 7 1
100	15 25 50 100	265 78 11 1
200	15 25 50 100	4190 1240 170 16
300	25 50 100 250	7450 1020 95 2
500	50 100 250 500	11800 1100 26 1
750	100 250 500 750	8900 210 7 1
1000	250 500 750 1000	1020 40 5 1

Table b
Non-Volatile Residue

Level	Quantity NVR
A	Less than 1.0 mg
B	1.0 mg to 2.0 mg
C	2.0 mg to 3.0 mg
D	3.0 mg to 4.0 mg
E	4.0 mg to 5.0 mg
F	5.0 mg to 7.0 mg
G	7.0 mg to 10.0 mg
H	10.0 mg to 15.0 mg
J	15.0 mg to 25.0 mg

Figure 1. Classification of Cleanliness Levels. Taken from MIL-STD-1246B. Table a lists the total quantity of particulates greater than a specific size (in microns) allowed per square foot of surface area. Table b expresses the quantity of non-volatile residue (NVR) per square foot associated with different NVR levels.

Figure 2. Visibly Clean Levels. Taken from NASA-JSC-SN-C-0005. THEMIS hardware will be inspected to a Visibly Clean, Highly Sensitive level.

VC Level	Incident Light Level (1)	Observation Distance	Remarks
Standard	≥ 50 foot-candles	5 to 10 feet	(2) (3) (5)
Sensitive	≥ 50 foot-candles	2 to 4 rwt.	(2) (3) (5)
Highly	≥ 100 foot-candles	6 to 18 inches	(3) (4)

NOTES:

(1) One foot-candle (lumens per square foot) is equivalent to 10.76 lumens per square meter.
(2) Cleaning is required if the surface in question does not meet VC under the specified incident light and observation distance conditions.
(3) Exposed and accessible surfaces only.
(4) Initial cleaning is mandatory; Note (2) applies thereafter.
(5) Areas of suspected contamination may be examined at distances closer than specified for final verification.

Non-flight covers will prevent contamination from accumulating on critical portions of the external surfaces of ESA and SST in excess of the Level 500A delivery value. The non-flight covers will remain installed at all possible times, and may only be removed at the instrumenter's request or as required for environmental testing. If the non-flight covers must be removed, all spacecraft surfaces in the vicinity must be inspected and cleaned if necessary to meet Visibly Clean Sensitive. In addition, the external surfaces of ESA and SST, as well as the interior surfaces of the non-flight covers, will be vacuumed and verified to meet Level 500A prior to re- installation of the covers. The external surface of the non-flight covers may be kept at a Visibly Clean, Sensitive level per NASA-JSC-SN-C-0005 while installed for routine integration and test operations.

Since the microchannel plates are susceptible to hydrocarbon contamination, precautions must be taken to prevent damage from solvents during spacecraft cleaning. Spacecraft cleaning should only be performed with the non-flight covers installed and the instrument purge operational. The THEMIS PM and MAM

should be notified before spacecraft level cleaning operations are performed. Reagent grade IPA is the recommended solvent for all spacecraft cleaning.

The humidity in the instrument environment should be kept between 35 and 50 percent to prevent condensation. The humidity must always be maintained above 35 percent in spacecraft facilities to reduce the likelihood of ESD. The temperature should be maintained at 70±5 °F.

Other contamination sensitive components in the THEMIS instrument include the spherical electric field probes used on the electric field booms. These probes are coated with DAG 213, a material with very limited cleanability. The electric field probes will be housed in protective covers at all times to prevent contamination accumulation on probe surfaces. The electric field probes and their protective covers will only be handled by the instrumenter or the instrumenter's representative.

The magnetometer booms and electronics box have no specific contamination requirements. These components will be maintained at the same cleanliness level as integrated subsystem surfaces.

A schedule for instrument cleaning and inspection is included in Table 7.1. The instrument providers are responsible for cleaning the exterior surfaces and maintaining the interior surfaces of the THEMIS instrument. All handling of internal instrument components will be done by the instrument developer in a Class 1000 or better clean bench.

5.2 PROBE SUBSYSTEMS

Unlike the instrument components described above, the THEMIS subsystems do not have any contamination requirements derived from science goals. There are, however, some subsystem surfaces which must remain clean for effective operation. For instance, the thermal properties of optical solar reflectors (OSRs) used in spacecraft radiators can be degraded if molecular contaminants accumulate on OSR surfaces and undergo photopolymerization on-orbit. The optical properties of solar cells employed by the power subsystem can also be diminished if the cells become obscured by contaminants. Some other spacecraft surfaces, such as indium tin oxide (ITO) coated thermal blankets, are relatively insensitive to contamination, but must remain contamination-free because the surfaces are too fragile to be effectively cleaned,

Precautions need to be taken to maintain the cleanliness of sensitive surfaces and surfaces with limited cleanability. The surfaces should be covered with approved bagging material during contamination generating activities, periods of

inactivity, and occasions when the components must be removed from the clean area.

All integrated subsystem surfaces will be maintained at a Visibly Clean, Sensitive level per NASA-JSC-SN-C-0005 during routine integration and test operations. Additional pre-launch cleanliness requirements may be imposed by the Probe vendor if required for subsystem performance reasons.

6. CONTAMINATION CONTROL IMPLEMENTATION

The THEMIS contamination requirements described in Section 5 will be met through a variety of contamination control measures. These measures are detailed in the following section.

6.1 MANUFACTURING

The design of the THEMIS Probes and Probe Carrier will provide for contamination precautions and/or inhibitors. All planned operations must include contamination reduction considerations. A list of contamination control procedures for common fabrication operations is provided below. Any situations not described below should be referred to the MAM for resolution. All hardware except for the instruments will be cleaned according to the THEMIS Probe Cleaning and Verification Procedure (tbd).

6.1.1 INSTRUMENTS

The instrument developers are responsible for their own contamination control prior to delivery to the Probes. Upon delivery, the instruments will meet an external cleanliness level of 500A. Instruments will be built from low outgassing materials and their materials list will be reviewed and approved by the MAM. Instrument boxes and harnesses will undergo a bakeout at the end of their thermal vacuum sequences to clean up. All flight equipment will be stored in clean bags when not in clean environments.

6.1.2 PROBE SUBSYSTEMS

Most of the probe subsystems hardware manufacturing will occur in areas exceeding a Class 300,000 clean room specification, per FED-STD-209D. During manufacturing, the following handling requirements must be followed:

- During contamination generating operations such as drilling, welding, soldering, etc. contaminants (metal chips, dust, excess solder, etc.) will be cleaned off hardware as generated by vacuuming, and/or wiping.

- Lubricant deposits (grease/oil) will be cleaned off immediately using the appropriate solvents.

- Prior to applying coatings, paints, etc., surfaces will be cleaned and visually inspected to be visibly clean per Section 5 of this document.

- All areas that become inaccessible during the fabrication and assembly process will be thoroughly cleaned and visually inspected to be visibly clean per Section 5 of this document.

- After manufacturing, all hardware and components will be subjected to non-damaging gross cleaning procedures (particulate removal and washing with solvents) to result in a visibly clean article. The hardware and components will then be bagged to protect from recontamination.

6.2 ASSEMBLY

6.2.1 INSTRUMENTS

The instrument developers are responsible for their own contamination control prior to delivery to Probe integration. Upon delivery, the instruments must meet an external cleanliness level of 500A. The instrument developers will be responsible for maintaining and verifying the internal cleanliness of the instruments through launch.

6.2.2 PROBE SUBSYSTEMS

Assembly of subsystems will occur in a Class 100,000 clean area or better. During assembly, hardware will be inspected after contamination-generating activities and cleaned if necessary to prevent collection of contaminants. All cleaning will be done in accordance with the THEMIS Cleaning and Verification Procedure, (tbd). The following procedure summarizes the cleaning process to be used for piece parts prior to assembly:

- Piece parts will be vacuumed and/or wiped with solvent-dampened extracted wipes until no contamination is visible on the wipes.

- All surfaces, holes, penetrations, and crevices will be cleaned with IPA using extracted wipes. If the wipes are found to be inadequate, pre-cleaned (IPA soaked) swabs may be used. Continue cleaning until surfaces appear visibly clean per Section 5 of this document and no contamination is visually seen on wipes.

- Items remaining contaminated after solvent wiping should be ultrasonically cleaned.

- Inspect to be visibly clean per Section 5 of this document.

Before final assembly, the following cleaning procedure will be followed:

- Vacuum the entire surface of the previous assembly, giving attention to crevices, mating surfaces, rivet and hillock holes, etc,

- Blow all crevices and mating surfaces with filtered dry nitrogen. Vacuum off any remaining particulate matter.

- Inspect assembly for grease marks and deposits.

- Clean surfaces and grease marks with IPA soaked wipes until no contamination is visible on the wipes,

The following procedure will be used during and after assembly:

- During assembly, wipe and/or vacuum surfaces as contamination is generated, inspect and clean all surfaces to a Visibly Clean, Sensitive level before the surfaces become inaccessible during assembly.

- Following each assembly step, inspect assembled surfaces for accumulated contamination and wipe surface with IPA when the surface is no longer visibly clean.

- After assembly is complete, all surfaces will be cleaned. Follow the same cleaning procedure as before assembly (vacuum, nitrogen clean-off, IPA wipes). Once all contamination appears to have been removed, inspect to be visibly clean per Section 5 of this document.

6.3 INTEGRATION

THEMIS will be integrated at Swales Aerospace in a class 100,000 clean area per FED-STD-209D (see Figure 4). The facility will be cleaned every two weeks or when additional cleaning is deemed necessary by the MAM or I&T Manager. The facilities and operations will be governed by the THEMIS Clean Area and Personnel Operations Procedure, (tbd). Personnel must attend a cleanroom training class prior to working in the clean area. Cleanroom compatible smocks, hoods or caps, shoe covers and latex or nitrile gloves will be worn in the clean area. Cleanroom coveralls and hoods will be substituted for smocks and caps

when the non-flight covers are removed from ESA and SST and at the request of the MAM or I&T Manager. Polyethylene gloves will be worn when working with solvents. Swales will supply the cleanroom garments and re-stock the facility with clean garments as required. A control area will be established around the Probe to limit access and facilitate contamination control.

6.3.1 INSTRUMENTS

The THEMIS instrument complement must meet an external cleanliness level of 500A per MIL-STD-1246B in the integration area. The ESA & SST instruments will be purged continuously with Ultra High Purity GN_2 during integration. The purge may be interrupted for a period of no longer than 24 hours if absolutely necessary due to integration activities. After verification and during the integration process, the external surfaces of the instrument (or the external surface of the instrument cover for ESA, SST, and the electric field probes) will be inspected for visible cleanliness per Section 5 of this document every two weeks (unless the instrument is bagged for the entire period). If the instrument surfaces are not visibly clean, cleaning will take place until the surface passes inspection. The instrument provider is responsible for cleaning the instrument exterior surfaces and maintaining interior instrument surfaces. The hardware will be covered with project approved bagging material during periods of inactivity or when outside controlled areas. The ESA and SST non-flight covers will remain installed during routine integration activities and at all times when the instrument is outside the clean area. Any hardware that has been taken out of the clean area will be inspected for visible cleanliness per Section 5 of this document prior to re-entering the clean area.

6.3.2 PROBE SUBSYSTEMS

All hardware referred to in Section 8 of this document must be baked out according to the requirements in the THEMIS Subsystems Bakeout Plan, before integration takes place. Prior to instrument delivery, subsystems hardware may be brought into the Class 100,000 clean area in a visibly clean state per Section 5 of this document. Once in the clean area, hardware that is not bagged will be re-inspected for visible cleanliness every two weeks. Items failing inspection will undergo spot cleaning until visibly clean.

Integrated subsystems will be isolated with bagging material or cleaned to level Visibly Clean Sensitive just before instrument integration and at the request of the MAM or I&T Manager. Subsystems hardware must be verified to be visually clean per Section 5 before being brought into the controlled area. If the ESA and SST covers are not installed, all hardware that will be brought into the vicinity of the instrument must be verified to meet Level 500A. Hardware will be covered

with approved bagging material during periods of inactivity or when removed from the class 100,000 clean area.

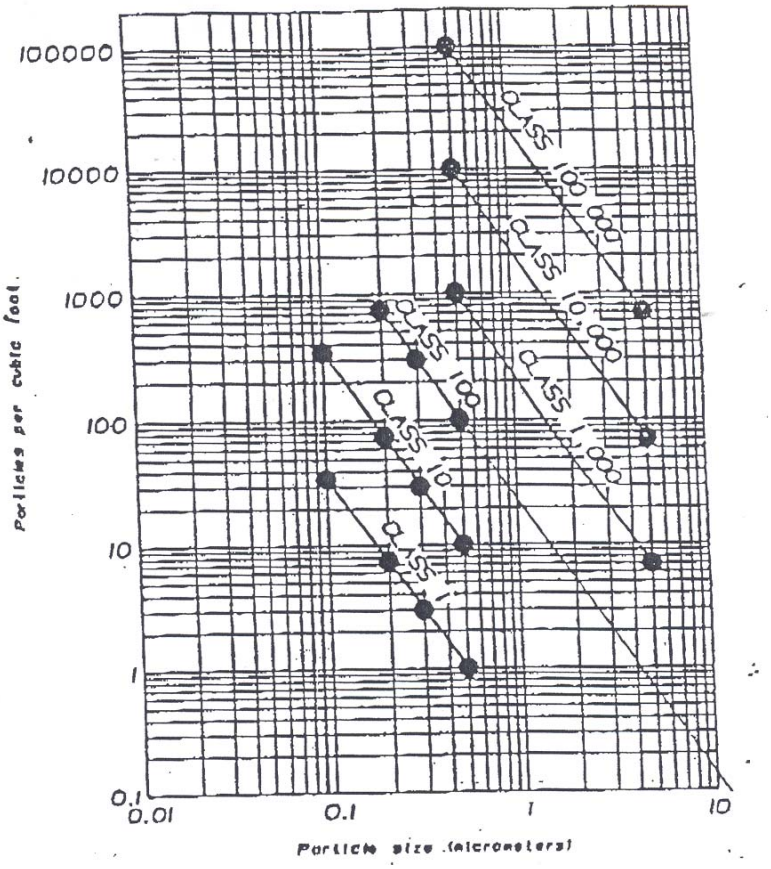

Figure 4. Class Limits. Taken from FED-STD-209D. The plot denotes the maximum number of particles equal to or greater than a specific size allowed per cubic foot of air.

6.3.3 THEMIS GROUND SUPPORT EQUIPMENT

All ground support equipment will be cleaned with IPA or bagged with Lumalloy or NMD-48100-PA1N prior to being taken into the clean area. Equipment that will come in contact with the flight hardware must be inspected for visible cleanliness as per Section 5 of this document.

6.4 TESTING

The THEMIS space probes and probe carrier will be moved from Swales Aerospace to GSFC or other facilities in the local area for environmental testing. All other testing will be done in a class 100,000 clean area. The probes will be

bagged and the instruments will be continuously purged with Ultra High Purity GN_2 during transport.

The bag and purge will remain on at all times except when prohibited by test activities. If the bag is removed for testing, personnel who come in the vicinity of the flight hardware will wear clean-room compatible smocks, hoods, shoe covers and latex gloves. A wrist strap and grounding wire is required to control electrostatic discharge. The wrist strap must be in contact with the bare skin of the wrist. When not in a clean area, the instrument purge can be interrupted for no longer than 24 hours. If the bag is removed for testing, the probes must be cleaned and recertified for visible cleanliness before being taken back into the clean area.

The thermal balance/thermal vacuum testing will be done in a cryo-pumped chamber. The chamber will be instrumented with a Quartz Crystal Microbalance (QCM) and a coldfinger. The ESA and SST internal apertures will be opened during thermal vacuum testing only if the chamber is deemed clean enough by the instrumentor and MAM. If the internal apertures are opened the chamber must also be equipped with a residual gas analyzer (RGA) to measure the partial pressure of contaminants. In addition, an oil-free vacuum system must be used and pre-test chamber particulate levels must be measured. A purge line will be connected to the ESA and SST during the test. Prior to thermal balance/thermal vacuum testing, a chamber bakeout and certification will be performed. Chamber requirements will be specified in the THEMIS Bakeout Plan. Following chamber certification, a coldfinger will be turned on for eight hours and a wash sample will be taken. Chamber contamination will be measured and identified prior to installation of flight hardware.

The THEMIS Bakeout Plan shall specify QCM placement and criteris to ensure that the outgassing requirements are met. Following the bakeout, a coldfinger will be turned on for eight hours and the chamber will be backfilled with Ultra High Purity GN_2. Once the chamber reaches ambient pressure and is accessible, a coldfinger sample will be taken.

6.4 TRANSPORTATION AND STORAGE

6.4.1 INSTRUMENTS

It is the instrument providers responsibility to deliver the instrument complement to Swales at cleanliness level 500A. During shipment, the instrument components will be bagged with project approved bagging material, and continuously purged with Ultra High Purity GN_2.

6.4.2 PROBE SUBSYSTEMS

Subsystem hardware that is not yet integrated has no special transportation and storage cleanliness requirements. At the time of integration, the hardware will be verified to the level specified in Section 6.3.2 by Swales. After cleaning, the hardware will be bagged with approved bagging material when outside a class 100,000 clean area except when precluded by integration and testing activities or when re-cleaning is deemed more appropriate. While in the clean area, the hardware will be covered with project approved bagging material during periods of inactivity.

6.4.3 PROBES

The spacecraft probes will be bagged when outside a class 100,000 clean area except when integration and test activities prohibit. While in the clean area, the spacecraft will be covered during periods of inactivity. The spacecraft will be bagged and transported from the integration area to the environmental testing area in the shipping container. During transportation to the launch site, the spacecraft will be bagged, purged and stored in a shipping container. The shipping container shall be fabricated from materials that do not out-gas at ambient conditions and do not shed particles (wood, bare aluminum, etc) unless a protective coating is applied. The spacecraft will be continuously purged with either humidity controlled and filtered air or nitrogen after installation in the launch vehicle shroud.

6.5 LAUNCH SITE OPERATIONS

THEMIS is planned for launch on a Delta launch vehicle from the Eastern Test Range (ETR). THEMIS will be bagged at all times when outside of a class 100,000 clean area, except when precluded by testing activities. The instrument's nitrogen purge will remain operational, and cannot be interrupted for periods longer than 24 hours. Once THEMIS is mated to the Delta, the fairing will be purged with either humidity controlled (35% to 50%) filtered air. Delta fairing air is guaranteed at Class 5000 at the inlet into the fairing. If necessary, Boeing can provide class 1000. The environment and handling requirements for KSC will be discussed in greater detail in the launch site implementation plans.

7. HARDWARE CLEANING AND VERIFICATION

7.1 CLEANING AND VERIFICATION SCHEDULE

During fabrication and initial assembly, visible gross contamination (oil, metal chips, etc.) will be cleaned from surfaces as it is generated. All mating surfaces will be vacuumed and solvent (acetone or IPA) wiped prior to mating. All areas to

be sealed during the fabrication/assembly process (compartments, boxes, modules, etc.) will be vacuumed and solvent cleaned before being sealed. Hardware will be cleaned to a visibly clean level per Section 5 prior to final assembly. Any contamination generated during assembly and integration will be immediately cleaned and the hardware surface inspected again. Re-cleaning will occur as necessary.

Prior to instrument delivery, all hardware being brought into the clean area will be inspected to be visibly clean per Section 5. Once the instruments have been delivered and integrated, cleanliness requirements will depend upon whether the non-flight covers are installed on ESA and SST. If the non-flight covers are installed, hardware will be inspected to be visibly clean per Section 5. If the non-flight covers are not installed, all hardware entering the instrument vicinity must be verified to be Level 500A.

Probe level inspection and cleaning will be performed on a regular basis throughout integration and test. Table 7.1 presents a baseline schedule of probe level inspection and cleaning operations. Additional cleaning or inspections may be scheduled at the request of the MAM, I&T Manager, or PM. The instrument provider is responsible for cleaning exterior instrument surfaces and maintaining interior instrument surfaces.

Molecular contamination levels will be verified with wash samples taken by Swales (Probe) or UCB (Instrument). Particulate contamination levels will be verified with tape lift samples. Results of both tests will be sent to the MAM. All visibly clean inspections will be performed by Swales or UCB.

TABLE 7.1 PROBE CLEANING AND INSPECTION SCHEDULE

Reason for Cleaning	Items to be Inspected, Cleaned	Required
Instr. Integration	Probe Bus	500A
Inspection	Integrated Probe	VC-HS
Post-Mass Properties	Integrated Probe	VC-HS
Post-Vibration	Integrated Probe	VC-HS
Post-EMI	Integrated Probe	VC-HS
Pre-Thermal Vacuum (Post-Magnetic Cal.)	Integrated Probe	500A
Post-Thermal Vacuum	Integrated Probe	VC-HS
Pro-Spin Balance	Integrated Probe	VC-HS

Launch Site Delivery	Integrated Probe	VC-HS
Fairing Installation	Integrated Probe	500A
Pre-Launch	Integrated Probe	500A

Notes: VC-HS = Visibly Clean, Sensitive per NASA-JSC-SN-C-0005.

7.2 CLEANING AND VERIFICATION ROLES AND RESPONSIBILITIES

The cleaning/verification roles and responsibilities listed below apply to the THEMIS instrument and subsystems upon arrival at Swales:

- The surface cleanliness requirements for each element will be established by the THEMIS MAM.
- The cleaning/verification procedures will be written by Swales and UCB.
- The implementation of the Contamination Control Plan, which includes coordination, scheduling, transport, storage, and actual cleaning of hardware, will be the responsibility of Swales and UCB.
- Molecular surface wipes/washes will be taken by Swales or UCB.
- Particle tape verification tests and monitoring of hardware operations listed above will be the responsibility of Swales and UCB
- The THEMIS MAM will receive and assess documented results.
- The instrument provider is responsible for cleaning exterior instrument surfaces and maintaining interior instrument surfaces.

7.3 Design for Cleanability

At satellite integration, all external surfaces shall be capable of being cleaned with low particulate, low NVR, polyester or similar texture wipes, soft bristle brushes, and isopropyl alcohol. Additionally, surfaces should be capable of being vacuumed. If the surface cannot be cleaned or cannot be cleaned frequently, the design organization shall include this information in the contamination control plan/handling procedures for this item and provide a copy to the THEMIS

Contamination Engineer. The THEMIS surfaces that cannot be easily cleaned are:

- SSD Devices
- Microchannel plates
- OSR's
- ITO coated MLI
- Following paints: DAG 213
- Composite coatings (lightly cleaned with care)

Covers shall be installed to protect these areas whenever possible. They shall be identified as non-flight items.
Designs should be free of recesses and blind holes where contaminants can become trapped. Fasteners locations should be chosen to preclude particles falling into an area/volume which cannot be cleaner once the fastener is installed. Textured finishes such as inorganic paints tend to retain particles and are difficult to clean and should be avoided near particulate sensitive surfaces. Vent locations shall be chosen to avoid line of sight to sensitive surfaces.

8. BAKEOUT REQUIREMENTS

A vacuum bake-out may be required for THEMIS's thermal blankets, electrical harness, and solar arrays. Additional bake-outs may become necessary if it is determined that material outgassing from other hardware jeopardizes the mission. Specifications for the THEMIS bake-outs will be detailed in the THEMIS Subsystems Bake-out Plan,(tbd).

8.1 CHAMBER BAKEOUT AND CERTIFICATION

Prior to baking out each piece of hardware, a chamber bakeout and certification will be performed with ground support equipment installed, in accordance with the THEMIS subsystems Bakeout Plan. The chamber is certified when the QCM, registers a change of less than or equal to the rate indicated in the bake-out plan for five consecutive hours. Following chamber certification, a cold-finger will be turned on for eight hours.

8.2 HARDWARE BAKE-OUT AND CERTIFICATION

Immediately following the chamber bake-out and certification, the flight hardware will be installed in the vacuum chamber. The hardware will be baked out at the highest allowable temperature as determined in the bake-out plan. The hardware shall be certified at its maximum on-orbit operating temperature with the QCM at the temperature of the coldest sensitive surface as specified in the bakeout plan. Following the hardware certification, a cold-finger will be turned on for eight

hours. A cold-finger wash will be taken after the chamber has been opened. For details, refer to the THEMIS Subsystems Bake-out Plan.

8.3 BAKEOUT DOCUMENTATION

Output from each of the bake-outs will include the QCM readouts, cold-finger wash test results and temperature and pressure history. This information will be sent to the THEMIS MAM.