Report 10353D
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Earth Observing System/Meteorological Satellite (EOS/METSAT) Advanced Microwave Sounding Unit-A (AMSU-A) Contamination Control Plan

Contract No: NAS 5-32314
CDRL: 007

Submitted to:

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INTRODUCTION

1.1 *Overview of plan*

This Contamination Control Plan is submitted in response to Contract Document Requirements List (CDRL) 007 under contract NAS5-32314 for the Earth Observing System (EOS) Advanced Microwave Sounding Unit A (AMSU-A). In response to the CDRL instructions, this document defines the level of cleanliness and methods/procedures to be followed to achieve adequate cleanliness/contamination control, and defines the approach required to maintain cleanliness/contamination control through shipping, observatory integration, test, and flight. This plan is also applicable to the Meteorological Satellite (METSAT) except where requirements are identified as EOS-specific.

This plan is based on two key factors:

a. The EOS/METSAT AMSU-A Instruments are not highly contamination sensitive.

b. Potential contamination of other EOS Instruments is a key concern as addressed in Section 9.0 of the Performance Assurance Requirements for the EOS/METSAT Integrated Programs AMSU-A Instrument (PAR) (NASA Specification S-480-79).

In addition to providing a contractual submittal fulfilling the requirements of CDRL 007, this Contamination Control Plan has been used within the project team, and within the larger network of Aerojet management, to formulate and intercommunicate our plan of action for the EOS/METSAT AMSU-A program.

1.1.1 *Relationship to other CDRLs*

This Contamination Control Plan is the final Critical Design Review submittal, and is consistent with the instrument design, the Performance Verification Plan (CDRL 022), and the Fabrication and Assembly Flow Plan (CDRL 023). This Contamination Control Plan covers the issue of materials outgassing, also covered in Section 6.0 of the Performance Assurance Implementation Plan (Aerojet Report No. 10399) and Section 9.0 of NASA Specification S-480-79. Implementation of this Contamination Control Plan is monitored and audited by Quality Assurance, in accordance with Section 8.0 of the Performance Assurance Implementation Plan (Aerojet Report No. 10399).

Post-delivery Contamination Control requirements on the spacecraft contractor are defined in the Interface Control Document (ICD) (CDRL 516), and are summarized in this plan for reference only.

1.2 *Referenced documents*

The following documents are referenced or applicable to this report. Unless otherwise specified, the latest issue is the issue in effect.

1.2.1 *Government documents*

1.2.1.1 *Military*

SPECIFICATIONS

MIL-P-27401	Propellant, Pressurizing Agent, Nitrogen
MIL-C-28809	Circuit Card Assemblies, Rigid, Flexible, and Rigid-Flex

STANDARDS

FED-STD-209	Clean Room and Work Station Requirements, Controlled Environment
MIL-STD-1246	Product Cleanliness Levels and Contamination Control Program

1.2.1.2 *NASA*

SPECIFICATIONS

GSFC 422-11-12-01	General Interface Requirements Document (GIRD) for EOS Common Spacecraft/Instruments
GSFC 420-05-01	Earth Observing System (EOS) Performance Assurance Requirements (PAR) for EOS General Instruments
GSFC S-480-79	Performance Assurance Requirements for the EOS/METSAT Integrated Programs AMSU-A Instrument (PAR)

REPORTS

1124	Outgassing Data for Selecting Spacecraft Materials

1.2.2 *Non-government documents*

1.2.2.1 *Aerojet documents*

SPECIFICATIONS

AE-25367	Preparation of Materials and Equipment Used for Cleaning Operation
AE-26060	Inspection, Cleaning, and Lubrication Procedures for Ball Bearings and Lubricant Reservoirs, AMSU-A
AE-26497	Cleaning Procedure for AMSU-A Instruments
AE-26675	Cleaning of Silvered Teflon
AE-26676	Cleaning of Second-Surface Mirrors
AE-26677	Cleaning of AMSU-A Instrument

STANDARDS

STD-2454	Requirements for Electrostatic Discharge Control

DRAWINGS

1331129	CCA, Scan Control Interface
1331200	METSAT AMSU Assembly A2
1331253	Blanket, Insulation
1331626	Blanket, Insulation
1331720	METSAT AMSU Assembly A1
1356006	EOS-AMSU Assembly A2
1356008	EOS-AMSU Assembly-A1

REPORTS

10333	Contamination Analysis – Apiezon Oil C on EOS/AMSU Instruments
10360	Performance Verification Plan
10361	Fabrication and Assembly Flow Plan
10380	Materials, Processes, and Lubricants List
10399	Performance Assurance Implementation Plan
10687	As-Built Materials List

1.2.2.2 *American Society for Testing and Materials*

ASTM-E-595	Total Mass Loss (TML) and Collected Volatile Condensable Materials (CVCM) for Outgassing in a Vacuum Environment

1.3 *Compliance with requirements*

1.3.1 *CDRL requirements*

This plan is structured to comply with the Description of Required Data for CDRL 007. Table I lists the requirements of CDRL 007 and the location in this Plan where each is covered.

1.3.2 *GIRD requirements*

Table II lists the Contamination Control requirements of the GIRD and the location in this Plan where each is covered.

1.3.3 *PAR requirements*

Table III lists the Contamination Control and related requirements of the PAR and the location in this Plan where each is covered.

1.4 *Organization responsible for each requirement*

1.4.1 *Implementation requirements*

Implementing all requirements of the Contamination Control Plan is the responsibility of the Contamination Control Engineer, except:

a. Measuring outgassing in the final cycle of thermal vacuum (PAR 9.3B) is the responsibility of the Test Engineer on the System Engineering Integration and Test Product Team (SEIT PT).

b. After delivery of the Instrument, Aerojet will verify cleanliness (and clean, if necessary) at the Spacecraft Contractor's facility. Implementing all other post-delivery Contamination Control requirements of the ICD is the responsibility of the spacecraft contractor.

1.4.2 *Auditing responsibility*

Quality Assurance is also responsible for auditing all operations to ensure compliance with all Contamination Control requirements. Audits shall be conducted per PAIP Section 1.9 and 8.27.2

1.5 *List of assurance services that may be procured*

Contamination-control related services that may be procured, with proposed subcontractor, are listed below:

a. Spectral Reflectance Measurements (on witness plates) — TRW

b. Residue Analyses — SEAL Labs or High-Rel Labs

Table I. CDRL 007 Requirements for Contamination Control Plan

	CDRL 007 REQUIREMENTS FOR CONTAMINATION CONTROL PLAN	LOCATION IN PLAN
A.	Pre-flight:	—
1.	Define the methods, procedures, and schedule requirements for integrating observatory instruments contamination control requirements in this control plan.	Overall Plan
2.	Define methods for determining a budget for allowable accretions for each phase of the program	2.1.2, 2.1.3, 2.1.4,
3.	Define levels of cleanliness and methods/procedures to be followed for this Project, from start of contract to end of mission.	2.1.3, 2.1.4
4.	Identify critical fabrication and assembly activities that will be performed in clean rooms or in clean room benches at the 100,000 or 10,000 class level. Provide an integrated operations flow chart.	3.1
5.	Identify controls over atmospheric contaminants, temperature, and humidity that will be used during electronic fabrication (including soldering), integration, testing, transportation, and launch. Indicate how other controls will meet the requirements, including a description of all facilities that will be used.	3.1, 3.2
6.	Identify design features of shipping containers that will keep contamination of flight hardware during shipping and storage within the contamination budget.	2.2.3
7.	Define the requirements and methods/procedures required to maintain cleanliness during spacecraft and laboratory fabrication, integration, and test.	2.1.4
8.	Show that the efforts to control contamination are consistent with controls to prevent electrostatic damage.	2.2.2
9.	Indicate the methods and frequency for monitoring cleanliness levels and accretions to ensure compliance with requirements.	3.1
10.	Define criteria for materials selection and acceptance relative to contamination control.	2.2.1
11.	Specify criteria for bake-out of critical subsystems.	2.2.4
12.	Provide a contamination training program. Personnel required to work in clean areas with flight hardware must be trained in clean area procedures.	2.2.6
13.	Define overall vent location and orientation policy, indicating how unintentional venting shall be avoided.	2.2.1.3
14.	Identify cleaning, inspection, and bagging to be used for parts, flight subassemblies, and assembled instrument. Identify how other activities will meet the requirements, and reference the procedures used for these activities.	2.2.2, 2.2.3, 2.2.5
B.	Flight	—
1.	Define the design requirements and design approach for contamination control for Launch operation through mission.	2.1.3, 2.1.4

Table II. GIRD Requirements for Contamination Control

	GIRD REQUIREMENTS FOR CONTAMINATION CONTROL	LOCATION IN PLAN
7.1.1	Cleanliness requirements for all sensitive instrument surfaces that are exposed during spacecraft I & T and launch site processing shall be submitted and documented in the ICD.	2.1.4.1
7.1.2	Prior to integration with the spacecraft, the instrument provider shall verify the cleanliness of instrument exterior surfaces by test.	2.3.2, 2.1.4.6
7.2	The instrument provider shall identify all sources of contamination that can be emitted from the instrument and shall document these in the ICD.	2.1.4.
7.3.1	The number, location, size, vent path, and operation time of vents shall be defined in the ICD.	2.1.4. 2.2.1.3
7.3.2	The Spacecraft Contractor shall position the instrument such that the contamination products from the vents of one instrument will not directly impinge on another instrument's contamination-sensitive surface nor directly enter another instrument's aperture.	2.1.4.3
7.4.1	The Instrument Provider shall provide instrument protective covers and specify procedures for their use. Specify in the ICD if and when protective covers are required to keep the instrument clean during Integration and Testing.	2.1.4.4
7.5	Instrument purge requirements, including type of purge gas, flow rate, gas purity specifications, filter pore size, type of desiccant (if any), and whether interruptions in the purge are tolerable shall be documented in the ICD.	2.1.4.5
7.6	Any required inspections or cleaning of instrument during I&T shall be defined in the ICD. Instrument Provider is responsible for cleaning the instrument.	2.1.4.6
7.7	Contamination Analysis Requirements: The instruments shall be designed to function in the on-orbit contamination environment, as follows: a. Cleanliness of the spacecraft surfaces meet Level 600A per MIL-STD-1246. b. Flux of molecular contaminants into the instrument apertures shall not exceed 5×10^{-14} g/cm^2-s.	
7.8	The Spacecraft Contractor shall provide the Instrument Provider with plume flow field analyses. The flow field analysis results shall include: a. Identity and quantity of each chemical species emitted b. Density as a function of spatial position c. Velocity or flux as a function of spatial position d. An equation or group of equations describing the plume	2.1.3.2
7.9	Instrument shall perform within specification limits under exposure to the on-orbit atomic oxygen environment. Materials exposed to atomic oxygen shall not generate contaminants.	2.2.1.2
7.10	Particulate and Molecular Cleanliness: The instruments will be integrated with the Spacecraft in a Class 10,000 clean room environment and maintained in that environment as much as possible during the integration and test flow.	2.1.3.1
7.11	Any GSE that must accompany the instrument into a clean room area must be cleaned and clean room-compatible. Any GSE that must be in the vacuum chamber during thermal-vacuum testing must be cleaned and vacuum compatible.	2.2.2.9

Table III. PAR Requirements for Contamination Control

	PAR REQUIREMENTS FOR CONTAMINATION CONTROL	LOCATION
6.2.4	Only those materials with a total mass loss (TML) less than 1.00 percent and collected volatile condensable materials (CVCM) less than 0.10 percent are acceptable. 1/	2.2.1.1
6.4	Provide Materials Lists, including: Polymeric Materials List, Inorganic Materials List, Lubrication List, and Materials Processes List.	2.3.1
9.1	Applicability and Definitions: A contamination control program shall be conducted to meet the needs of the instrument and EOS/METSAT Project.	Overall Plan
9.2	Prepare and implement a Contamination Control Plan that includes contamination allowances, methods for control, and verifications that allowances have been met.	Overall Plan
9.2.1	Establish allowances for performance degradation of contamination-sensitive hardware. Include the following: a. The sensitivity of the instrument to contamination, the contamination control concerns, and potential sources of contamination. b. The science requirements and allowable performance degradation. c. Allowances for all sensitive surfaces. Document all analyses.	2.1.4.1
9.2.2	Prescribe measures to ensure that contamination allowances are not exceeded.	2.3
	Include a description of the facilities, and a description of all procedures used after fabrication and during integration and test, interfacing with other subsystems or the observatory, cleaning, bagging, transportation, etc. An operations flow chart shall be included.	3.1
	Total amount of outgassed condensable volatile matter must stay within the outgassing and particulate contamination allowances in PAR section 9.2.1, even though materials satisfy PAR section 6.2.4.	2.1.4, 2.2.1
	Instruments shall be designed so that gasses vented during ascent and on-orbit will be directed away from contamination-sensitive surfaces or areas of the developer's instrument and adjacent instruments.	2.2.1.3
	Detail the methods of verification to be used during each phase of the hardware lifetime. For each method, the documented procedure and data recording requirements must be enumerated or referenced. Include criteria for defining out-of-control conditions and planned methods of dealing with them.	2.3
9.2.3	Bake-outs of wiring harnesses, thermal blankets, and radiator mirror panels are required. For highly contamination-sensitive instruments, bake-outs of critical subsystems before final instrument assembly may also be necessary.	2.2.4.1, 2.3.4.1
9.2.4	Thermal Vacuum Test: The Contamination Control Plan shall include or reference the contamination controls to be exercised in preparing the thermal-vacuum chamber and the necessary fixtures and stimuli for system level tests. Contingency plans dealing with the possibility that contamination criteria are exceeded shall be included.	2.2.4.2, 2.3.4.2, 2.3.4.3, 2.3.5
9.3A	The external surfaces of all EOS instruments shall be at Level 600A or better (per MIL-STD-1246) upon delivery to the integration contractor. Surface cleanliness levels shall be verified upon delivery to the observatory contractor.	2.3.2.3
9.3B	At the last hot cycle of the instrument-level thermal-vacuum testing, all EOS instruments shall outgas at a rate less than or equal to 1×10^{-7} g/cm^2-hr for 5 consecutive hours.	2.2.4.2, 2.3.4.2, 2.3.4.3, 2.3.5

NOTE:

1. Non-conforming materials are listed in Report 10380, Materials, Processes, and Lubricants List (CDRL 506)

SECTION 2

CONTAMINATION CONTROL METHODS

Contamination control methods are divided into four areas, as shown in Figure1.

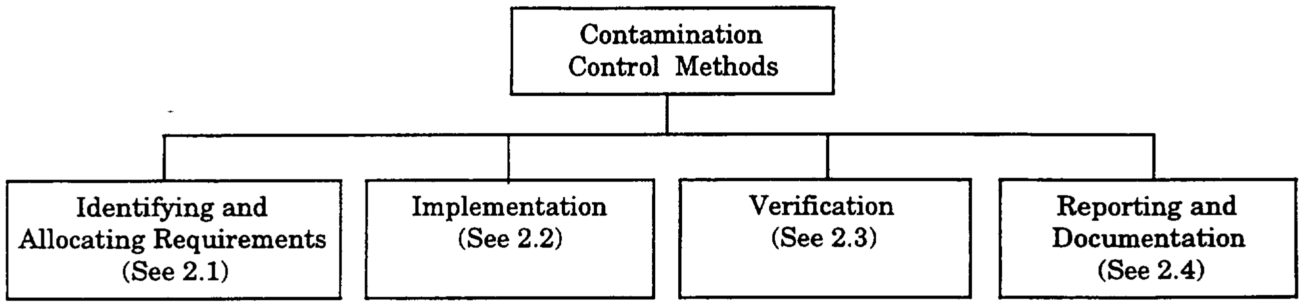


Figure 1. Contamination Control Methods Tree

2.1 *Identifying and allocating requirements*

The Requirements Identification and Allocation process is accomplished by executing the four tasks shown in double-lined boxes on Figure 2.

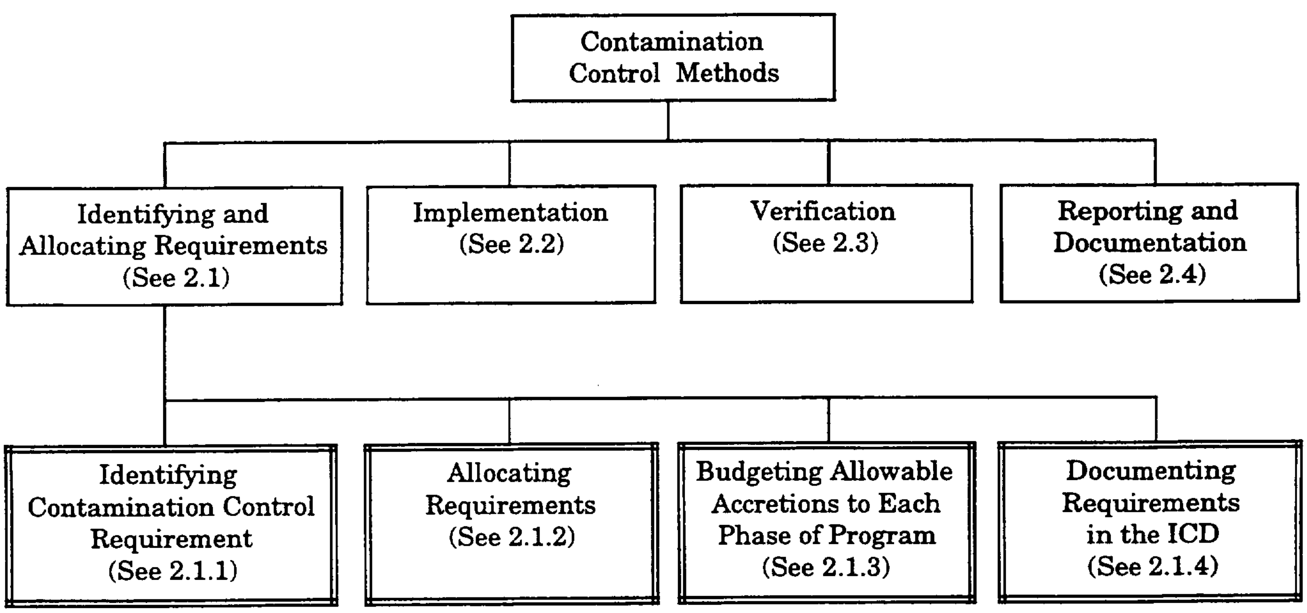


Figure 2. Requirements Identification and Allocation Tasks

2.1.1 *Identifying contamination control requirements*

Contamination Control requirements fall into three categories; Cross-Contamination Generation (CCG), Self-Contamination Generation (SCG), and Instrument Contamination Susceptibility (ICS). In addition to the quantitative requirements of CCG, SCG, and ICS, there are contractual requirements on the processes used to produce the EOS/METSAT AMSU-A instrument (bakeout, GSE cleaning, etc.). These are discussed in 2.1.1.4.

2.1.1.1 ***Cross-contamination generation requirements.*** Cross-Contamination Generation (CCG) is the undesired generation of contamination that can adversely affect other instruments on the spacecraft. Cross-Contamination Generation requirements are defined by contractual documentation, and are summarized below:

GIRD 7.9	Atomic Oxygen Contamination: The instruments and Spacecraft shall perform within specification limits under exposure to the on-orbit atomic oxygen environment. Instrument or Spacecraft materials exposed to atomic oxygen shall not generate contaminants (e.g. particulates, chemical reaction products) as a result of interaction with the atomic oxygen environment.
PAR 6.2.4	Only those materials with a total mass loss (TML) of less than 1.00 percent and collected volatile condensable materials (CVCM) of less than 0.10 percent when tested in accordance with ASTM E 595, are acceptable for general spaceflight use.
PAR 9.3	The external surfaces of all EOS instruments shall be at Level 600A or better (per MIL-STD-1246) upon delivery to the integration contractor. Surface cleanliness levels shall be verified upon delivery to the observatory contractor.
PAR 9.3	At the last hot cycle of the instrument-level thermal-vacuum testing, all EOS instruments shall outgas at a rate less than or equal to 1×10^{-7} g/cm^2-hr for 5 consecutive hours at the maximum instrument operating temperature.

2.1.1.2 ***Self-contamination generation requirements.*** Self-Contamination Generation (SCG) is the undesired generation of contamination by elements of the instrument that can adversely affect the AMSU-A instrument itself. SCG limits are defined by the EOS/METSAT AMSU-A developer and are documented in this plan and the ICD.

As part of the Systems Engineering activity, all contamination-critical surfaces have been identified, and maximum permissible contamination deposition limits have been developed for each. The results of these analyses are presented in the Instrument Description Document (IDD).

The thermal radiators are the most contamination-critical surfaces, as defined in Paragraph 7.1.1 of the IDD and 7.1 of the ICD. The deposition thickness limit for the end-of-life contamination for these thermal radiators is 500 angstroms for the A1 Instrument and 400 angstroms for the A2 Instrument.

2.1.1.3 ***Instrument contamination susceptibility requirements.*** Instrument Contamination Susceptibility (ICS) is the undesired effect of external contamination (in post-delivery handling, integration, launch, and mission environments) on the EOS/METSAT AMSU-A instrument. ICS requirements on the instrument developer are provided in GIRD 7.7 (which specifies on-orbit spacecraft surface cleanliness and molecular contaminant flux into the instrument apertures).

The sources and levels of this external contamination are defined below:

GIRD 7.10	During Integration: The instruments will be integrated with the Spacecraft in a Class 10,000 clean room environment and maintained in that environment as much as possible during the integration and test flow. Air cleanliness, NVR, and particle fallout rates shall be measured at regular intervals, satisfying, as a minimum, the requirements in FED-STD-209.
GIRD 7.7	On-Orbit: The instruments shall be designed to function in the on-orbit contamination environment, as follows: a. The cleanliness of the spacecraft surfaces meet Level 600A per MIL-STD-1246. b. The flux of molecular contaminants into the instrument aperture(s) shall not exceed 5×10^{-14} g/cm^2-s.

The GIRD also specifies that the spacecraft contractor shall provide plume flow analyses to the instrument contractor (when they become available) for comments and recommendations.

2.1.1.4 ***Contractual process requirements***. Process requirements are also defined in the contractual documents. These are summarized below:

GIRD 7.1.1	GSE Cleanliness Requirements: Any GSE that must accompany the instrument into a clean room area must be cleaned and clean room-compatible. Any GSE that must be in the vacuum chamber during thermal vacuum testing must be cleaned and vacuum-compatible.
PAR 9.2.3	Bake-Outs: Bake-outs of wiring harnesses, thermal blankets, and radiator mirror panels are required since past experience has shown these to be major contributors to the contamination level of hardware in test and flight.

2.1.2 ***Method of allocating requirements***

Requirements are allocated to the specific Product Teams (PT) that have control over all or a portion of the parameters or processes involved in meeting the requirement. Allocations are performed by the System Engineering, Integration, and Test (SEIT) PT, and agreed to by the responsible PT.

2.1.2.1 ***Requirements allocation matrix***. The quantitative Contamination Requirements stated in 2.1.1.1, 2.1.1.2, and 2.1.1.3, as well as the Process Requirements stated in 2.1.1.4, are allocated to the applicable Product Teams as shown in the Requirements Allocation Matrix, Table IV.

The last requirement in Figure 2-1, PAR 9.3B, is allocated by analyzing the potential sources of outgassing in the AMSU-A instrument. From that analysis, requirements are allocated to ensure that these outgassing sources are controlled, as follows:

a. Bearing Lubricant – The requirement to ensure that the bearing lubricant is procured, handled, baked out, and protected so as not to worsen outgassing is directly allocated to the Antenna PT and is specified in AE-26060.

b. Thermal Blankets and Radiator Mirror Panels – The requirement to ensure that the thermal blankets and radiator mirror panels are cleaned and baked out is directly allocated to the Mech/Thermal PT and is specified in Aerojet Drawings 1331626, 1331253, 1331720, and 1356008.

c. Wiring Harnesses – The requirement to ensure that the wiring harnesses are cleaned and baked out is directly allocated to the Electronics PT and is specified in Aerojet Drawings 1331720, 1331200, 1356006, and 1356008.

d. Circuit Card Conformal Coating – The requirement to ensure that the conformally coated circuit cards are cleaned and baked out is directly allocated to the Electronics PT and are specified in Aerojet Drawing 1331129 and MIL-C-28809.

In addition to allocating requirements on these dominant outgassing sources, a number of good contamination control practice requirements are allocated to all hardware PT, as follows:

e. All parts and assemblies that have been machined, outside processed, special processed, or environmentally tested are cleaned to Visibly Clean (VC) conditions (see 2.2.2) prior to inspection. Then they are placed in clean protective packaging material.

f. All assembly is performed in a Class 100,000 work area. All in-process hardware is covered with clean protective material when not actually being used.

Table IV. Contamination Requirements on EOS/METSAT AMSU-A Hardware

	CONTAMINATION REQUIREMENTS ON EOS/AMSU-A HARDWARE	ALLOCATION
GIRD 7.7	Instruments shall be designed to function in the on-orbit contamination environment, as follows: a. The cleanliness of the spacecraft surfaces meets Level 600A of MIL-STD-1246. b. The flux of molecular contaminants into the instrument aperture(s) shall not exceed 5 x 10^{-14} g/cm^2-s.	Direct Allocation to SEIT PT
GIRD 7.9	Instruments and Spacecraft shall perform within specification limits under exposure to the on-orbit atomic oxygen environment. Instrument or Spacecraft materials exposed to atomic oxygen shall not generate contaminants (e.g. particulates, chemical reaction products) as a result of interaction with the atomic oxygen environment.	Direct Allocation to Mech/Therm Subsystem PT
GIRD 7.10	Instruments will be integrated with the Spacecraft in a Class 10,000 clean room environment and maintained in that environment as much as possible during the integration and test flow. Air cleanliness, NVR, and particle fallout rates shall be measured at regular intervals, satisfying, as a minimum, the requirements in FED-STD-209.	Direct Allocation to SEIT PT
GIRD 7.11	GSE Cleanliness Requirements: Any GSE that must accompany the instrument into a clean room area must be cleaned and clean room-compatible. Any GSE that must be in the vacuum chamber during thermal-vacuum testing must be cleaned and vacuum-compatible.	Direct Allocation to GSE PT
PAR 6.2.4	Outgassing characteristics of organic materials in vacuum shall be a prime consideration in their selection. Only those materials with a total mass loss (TML) of less than 1.00 percent and collected volatile condensable material (CVCM) of less than 0.10 percent when tested in accordance with ASTM E 595, are acceptable for general spaceflight use. Specific mission contamination control requirements may dictate more stringent outgassing criteria.	Direct Allocation to all Hardware PT
PAR 9.2.3	Bake-outs of wiring harnesses and thermal blankets are required since past experience has shown these to be major contributors to the contamination level of hardware in test and flight.	Direct Allocation to Sig Proc & Mech/ Therm PT
PAR 9.3A	The external surfaces of all EOS instruments shall be at Level 600A or better (per MIL-STD-1246) upon delivery to the integration contractor. Surface cleanliness levels shall be verified upon delivery to the observatory contractor.	Direct Allocation to SEIT PT*
PAR 9.3B	At the last hot cycle of the instrument-level thermal-vacuum testing, all EOS instruments shall outgas at a rate less than or equal to 1 x 10^{-7} g/cm^2-hr for 5 consecutive hours at the maximum instrument operating temperature.	Part Allocations to PT * (See following discussion)
	* Actual measurements are the responsibility of the Contamination Control Engineer, working on the SEIT PT.	

g. All completed hardware assemblies are cleaned to VC conditions prior to inspection. Then they are placed in clean protective packaging material.

h. All assemblies are cleaned to VC conditions prior to integration.

i. All integration is performed in a Class 100,000 work area. All integration hardware is covered with clean protective material when not actually being used.

j. Instrument assemblies and final configuration shall be covered during transport to and from testing areas outside the Class 100,000 assembly area.

k. Instrument final configuration shall be stored in cleaned, inspected shipping containers after completion of final testing and inspection.

2.1.3 ***Budget of allowable accretions for each phase of program***

Paragraphs 2.1.1 and 2.1.2 focus on the control of contamination during the construction of the AMSU-A instrument to meet the deliverable contamination requirements, both contractually imposed and derived from instrument self-contamination concerns. This paragraph focuses on the control of further contamination accretion as the instrument is integrated, tested, launched, and operated in-orbit.

2.1.3.1 ***Contractually-defined contamination-related environments in subsequent phases of the EOS/METSAT Program.*** The contamination-related environment during integration is specified in GIRD 7.10 (Class 10,000). Instrument purge requirements during integration and test of the spacecraft are specified in the ICD, per GIRD 7.5. Inspection and cleaning required during integration and test of the spacecraft are specified in the ICD, per GIRD 7.6. The integration and test process and environment is expected to contribute negligible accretion during integration of the AMSU-A.

The contamination-related environment during on-orbit operation is specified in GIRD 7.7 (spacecraft surfaces at Level 600A and molecular contaminant flux of 5×10^{-14} g/cm^2-s). This environment is expected to result in a degradation in solar absorptance of the instruments thermal surfaces of 0.1 and has been provided for in the instruments design.

2.1.3.2 ***Spacecraft contractor supplied analysis inputs*** After the spacecraft contractor determines the configuration of the EOS spacecraft, he will provide plume flowfield analyses for all thrusters, including any launch vehicle stages that fire after the payload fairing is jettisoned. The flowfield analysis results shall include: identity and quantity of each chemical emitted, density as a function of spatial position, including the "backflow region" at angles greater than 90 degrees from the plume centerline, velocity or flux as a function of spatial position, including the backflow region, and an equation or group of equations describing the plume.

This information is expected to be made available well after the EOS/METSAT AMSU-A CDR, and can thus have minimal effect on the instrument design. Aerojet will review the information from this analysis and will provide comments and recommendations if the plume flowfield introduces any risk in meeting the on-orbit performance requirements.

2.1.4 ***Requirement documentation in the ICD***

Contamination requirements that apply after the instrument is delivered to the spacecraft contractor are discussed in the following subsections and are documented in the ICD.

2.1.4.1 ***Cleanliness requirements for all sensitive instrument surfaces.*** Cleanliness Requirements for all sensitive instrument surfaces that are exposed during spacecraft integration, test, and launch site processing are documented in Section 7.1 of the ICD, per GIRD 7.1.1. The ICD states the following preliminary surface cleanliness requirements:

a. Thermal radiators on the A1 and A2 instruments and all other exterior surfaces:

b. No more than 500 Angstroms of contamination is allowable at the end of mission life for the A1 unit thermal radiators and exterior surfaces and no more than 400 angstroms for the A2 thermal radiators and exterior surfaces.

2.1.4.2 ***Identify all sources of contamination that can be emitted from instrument.*** All sources of contamination that can be emitted from the instrument are documented in Section 7.2 of the ICD, per GIRD 7.2. The preliminary contamination source list below includes total quantities of materials that may outgas:

	A1 Instrument	A2 Instrument	Temperature	Mass Flux
Second surface mirrors	0.0048 g	N/A	N/A	N/A
MLI blankets	0.0024 g	0.0730 g	N/A	N/A
Aluminized Kapton	N/A	0.0110 g	N/A	N/A
Silvered-Teflon	N/A	0.0035 g	N/A	N/A
Bearing Lubricant – A1, lower motor	0.21 g	N/A	38°C	1.3×10^{-9} g/sec
Bearing Lubricant – A1, upper motor	0.13 g	N/A	33°C	8.5×10^{-10} g/sec
Bearing Lubricant – A2	N/A	0.47 g	46°C	2.95×10^{-9} g/sec

Bearing lubricant loss is calculated as the product of the oil vapor mass flux at the temperature noted multiplied by the number of seconds in a five year period (1.58×10^{8}). Values shown for mass flux are from Figures 5 and 6 in the Appendix.

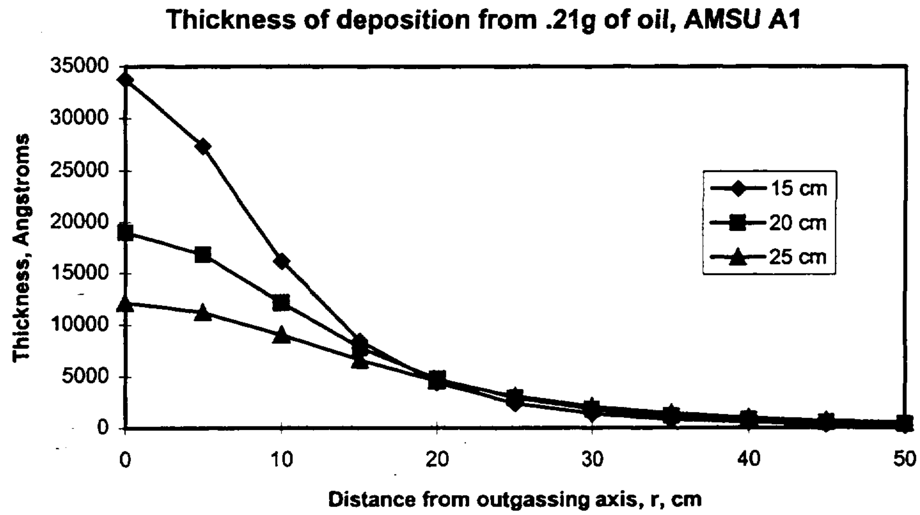
The instrument scan drive motors are lubricated with Apiezon C + organolead additive, a high outgassing lubricant. Analysis predicts that small amounts of lubricant will escape the bearings and may be deposited onto nearby surfaces. The A2 unit bearings are estimated to release about two times as much lubricant as the A1 bearings. The deposition thickness is strongly dependent on the spacing between instruments. The worst-case expected contamination of neighboring surfaces by the A1 is depicted in Figure 3. The worst case A2 bearing lubricant deposition is depicted in Figure 4. Contamination-sensitive instrument surfaces of other instruments aboard the spacecraft must be maintained at least 210 cm away from the A2 motor axis, and must not have unobstructed line of sight to the axis. The A1 motor axis is covered by MLI blankets and is a much less significant source of contamination.

2.1.4.3 ***Number, location, size, vent path, and operation times of vents.*** The number, size, vent path, and operation time of vents are documented in Section 7.3 of the ICD, per GIRD 7.3.1 and are defined in paragraph 2.2.1.3 of this document. From that information, the spacecraft contractor shall place the instrument such that the contamination products from the vents of one instrument will not directly impinge on another instrument's contamination-sensitive surface nor directly enter another instrument's aperture.

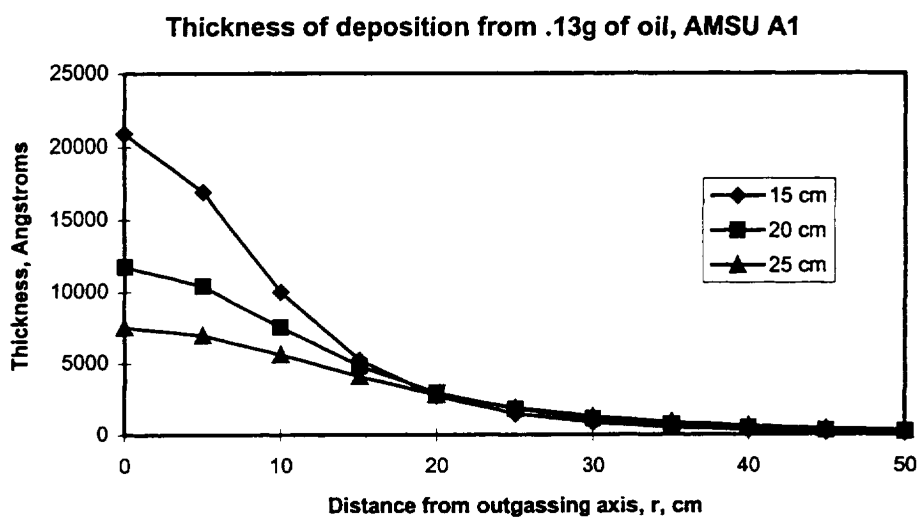
2.1.4.4 ***Protective cover requirements.*** Protective covers (such as bags, draping materials, or hard covers) required to keep the instrument clean during spacecraft integration and test are documented in the ICD. The preliminary protective cover requirements include:

a. Non-flight covers are provided by the instrument provider and must be maintained over feedhorns, the rotating portions of the instruments, and the antenna apertures during integration and removed before flight.

b. Covering and bagging material used for contamination protection must also provide electrostatic discharge (ESD) protection.



a. Lower Motor Bearing Lubricant

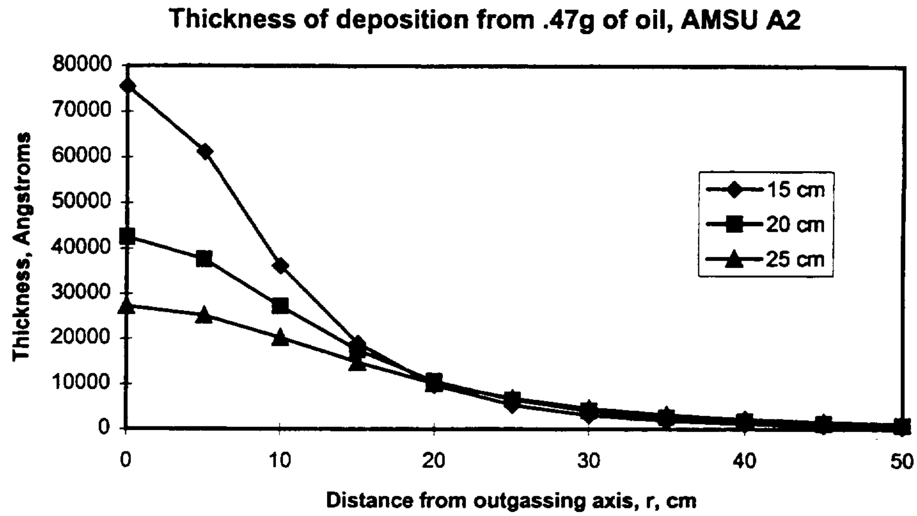


b. Upper Motor Bearing Lubricant

Figure 3. Analytical Prediction of Worst-Case Deposition from A1 Bearings

2.1.4.5 ***Instrument purge requirements.*** Instrument purge requirements during spacecraft integration and test, including type of purge gas, flow rate, gas purity specifications, filter pore size, type of desiccant (if any), and whether interruptions in the purge are tolerable are documented in Section 7.5 of the ICD. The preliminary instrument purge requirements include:

a. Dry nitrogen purge, conforming to the requirements of MIL-P-27401, Type I, Grade B or better, must be maintained on the scan motor bearings any time the instrument is outside a class 100,000 clean room area.



c. A2 Bearing Lubricant

Figure 4. Analytical Prediction of Worst-Case Deposition from A2 Bearings

b. Flow rate may be governed by a pressure regulator and set to a positive pressure of 3.0 to 5.0 psi.

c. Purge interruptions may occur as necessary such as during vacuum testing and required interruptions caused by assembly or test operations. Shipping container design permits purge during storage.

2.1.4.6 ***Instrument inspection and cleaning during spacecraft integration and test.*** Any required inspections or cleaning of the instrument during spacecraft integration and test are documented in Section 7.6 of the ICD. The Instrument Provider is responsible for cleaning the instrument prior to shipment and for inspecting the instrument upon unpacking at the spacecraft contractor. All subsequent inspection and cleaning operations specified on the ICD are the responsibility of the spacecraft contractor. The inspection and cleaning requirements during spacecraft integration and test will be recommended in the pre-CDR submission of the ICD and in the final submission of this Contamination Control Plan.

2.2 *Contamination control implementation*

Implementation of Contamination Control requirements defined in 2.1 is accomplished by executing the four tasks, shown in double-lined boxes on Figure 5.

2.2.1 *Design for contamination control*

2.2.1.1 ***Material selection for outgassing***. As stated in Section 6, Materials and Processes, of the Performance Assurance Implementation Plan (PAIP), outgassing characteristics shall be a prime factor in material selection, and only materials with a TML less than 1.00 percent and CVCM of less than 0.10 percent are acceptable. The Contamination Engineer/M&P Control Specialist provides a checklist of special M&P requirements, including the outgassing requirements, to the Product Team Leaders, and they follow-up through the design cycle to ensure that any special requirements receive special attention.

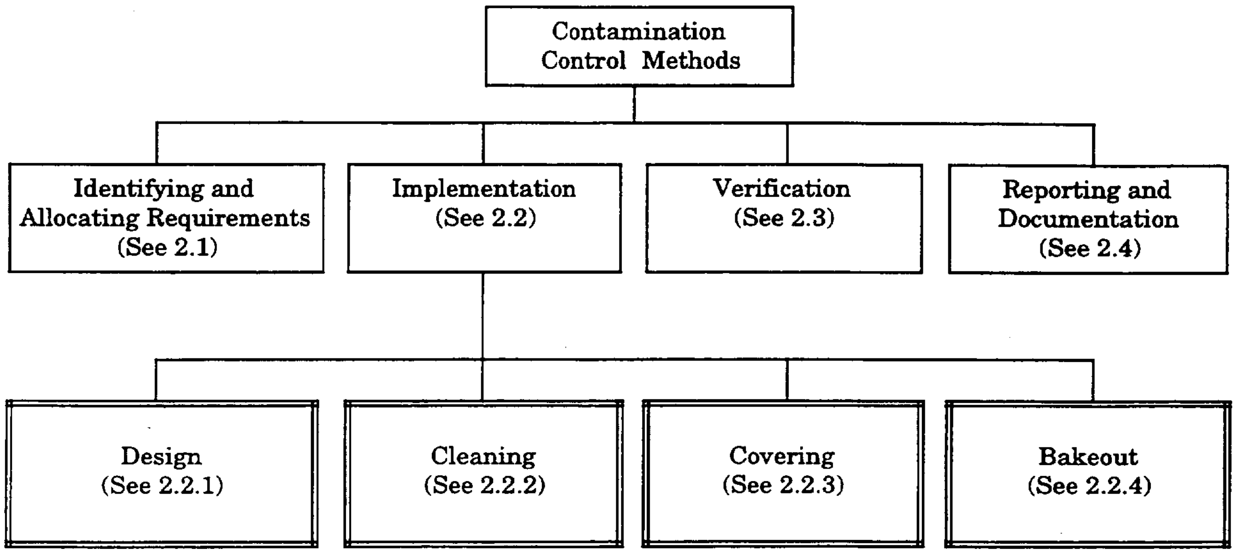


Figure 5. Contamination Control Implementation Tasks

Outgassing characteristics exceeding those stated in the requirements above may be approved by the PMPCB for usage on a limited basis, when application data demonstrate that the overall requirements of the instrument are met and the application does not compromise cross-contamination (instrument-to-instrument) requirements.

Specifically, the bearing lubricant exceeds the outgassing characteristics requirement but does not prevent compliance with the instrument level outgassing requirements. Report 10333, dated December 1993, *Contamination Analysis – Apiezon Oil C on EOS/AMSU-A Instruments*, provides the analysis which substantiates that the lubricant outgassing will still meet instrument outgassing requirements, although not meeting the TML and CVCM requirements on the material. This report is applicable to the METSAT instruments also.

Estimated TML of lubricant = 29 percent, estimated CVCM of lubricant = 14 percent.

2.2.1.2 ***Material selection for insensitivity to atomic oxygen***. An initial study of the effects of atomic oxygen on the exterior of the Instrument has been performed. Results show that only materials exposed directly to the velocity vector of the impinging atomic oxygen can be affected. Therefore, the material selection requirement has been directly allocated to the Mechanical/Thermal PT, to control the external materials, and the Antenna PT, to control the Composite Reflector backside coating.

Results also show that all metallic surfaces are unaffected by the atomic oxygen. Similarly, the thermal blankets and other exposed materials have been reviewed, and are expected to be unaffected by atomic oxygen.

2.2.1.3 ***Vent design***. Each of the AMSU-A instruments will have one vent tube with a tube size of 1/4 inch inside diameter. They will be located such that there is no line of sight to other instruments. The AMSU-A vents are open continuously, thus avoiding unintentional venting.

The venting of the A1 instrument is shown in Figure 6 and the bearing lubricant exit area is shown in Figure 7. For the A1 instrument, though the vent tube is adjacent to one of the antenna reflectors, apertures will not be in line of sight to any venting. The venting of the A2 instrument is shown in Figure 8 and the AMSU-A2 bearing lubricant vapor exit area is shown in Figure 9. The vent tube of the A2 instrument will be directly in front of MLI blanket materials, so gases will vent onto void areas of the blanket and will escape near Velcro attachments.

The vent designs on the EOS/METSAT AMSU-A instruments are identical with those on the NOAA/AMSU-A instruments.

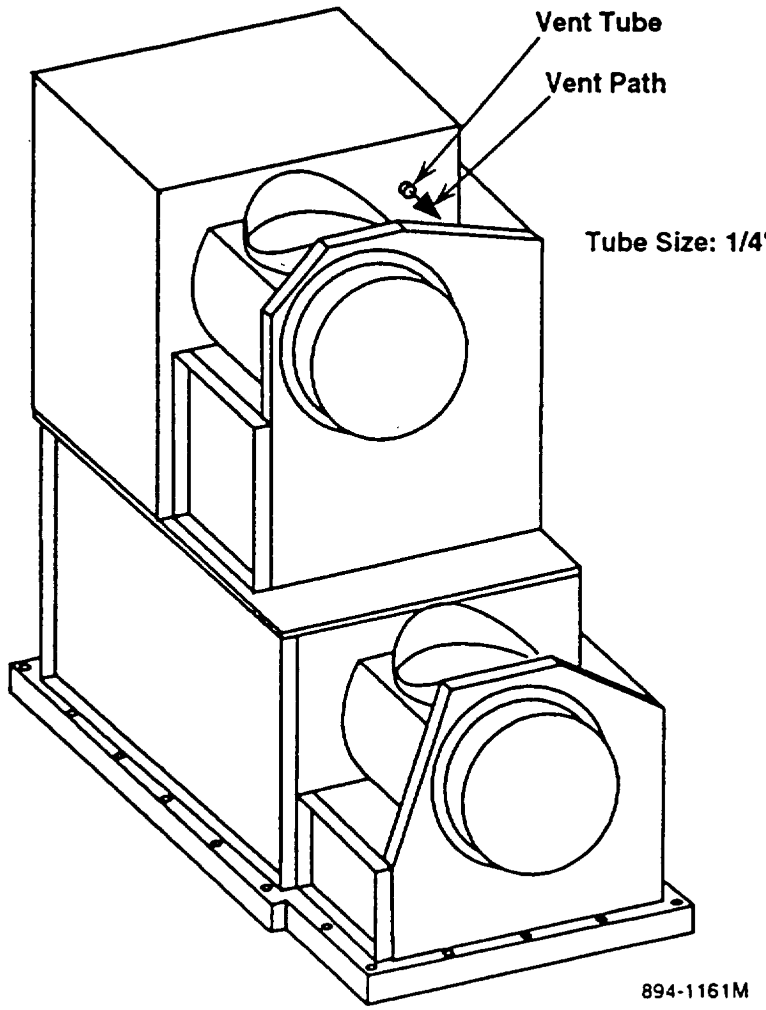


Figure 6. AMSU-A1 Vent Path

2.2.2 *Cleaning*

Cleaning in accordance with AE-26677 is performed at three levels:

Level A: Basic good housekeeping cleaning to achieve a Visibly Clean (VC) condition.

Level B: Cleaning to achieve a Visibly Clean condition and to remove surface volatile condensable materials.

Level C: Cleaning to achieve MIL-STD-1246, Level 600A surface cleanliness.

In all cases, the cleaning is followed by inspection (verification, covered in 2.3 and covering [bagging, covers, and containers], covered in 2.2.3).

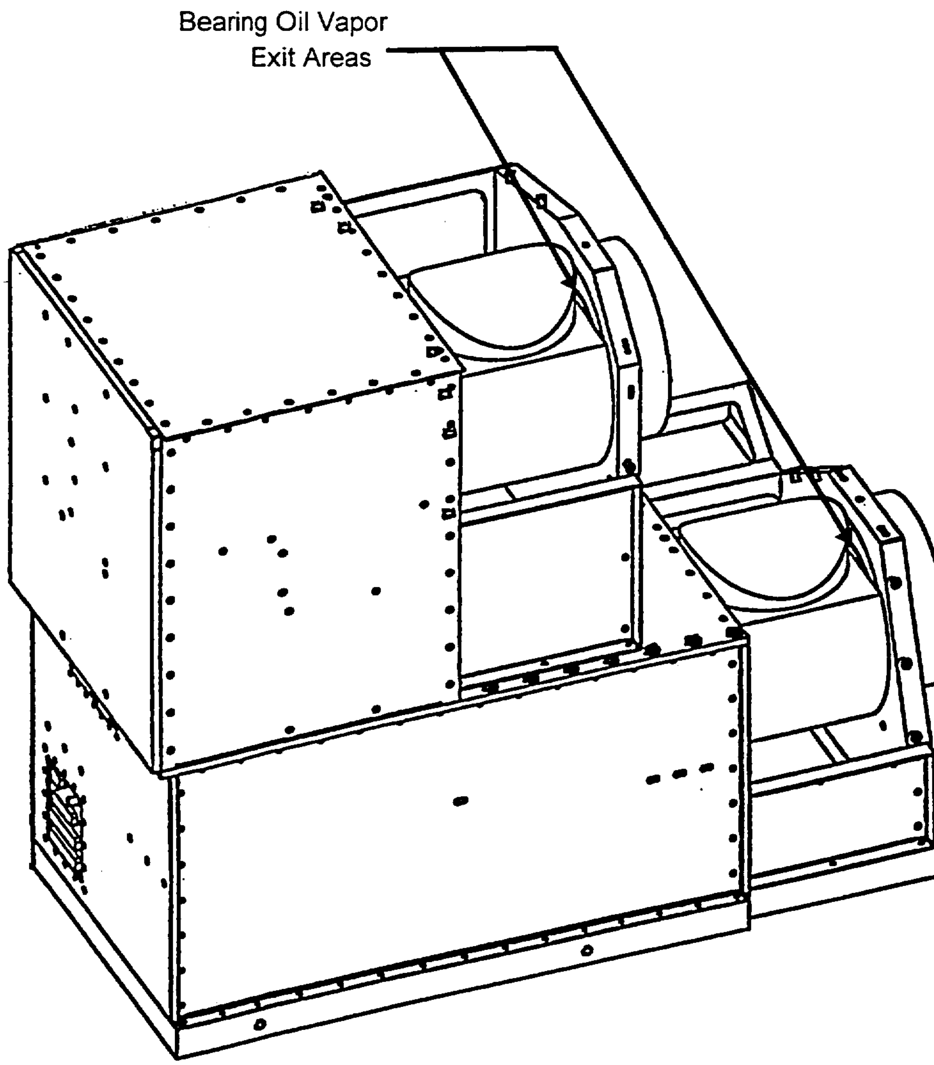


Figure 7. AMSU-A1 Bearing Lubricant Exit Areas

Cleaning Compatibility with ESD Requirements: All cleaning procedures will be conducted in compliance with Aerojet Standard STD-2454.

2.2.2.1 ***Fabricated parts.*** All fabricated parts shall be deburred and cleaned to a visibly clean level prior to permanent attachment. Vacuuming and wiping are the preferred particulate cleaning techniques. Any blowing operation should be performed away from the immediate assembly area, and high purity gaseous nitrogen (GN_2) or compressed air cans should be used.

All fabricated parts shall be free of visible particulate contamination at final inspection. All fabricated part inspection shall include inspection for a Visibly Clean condition.

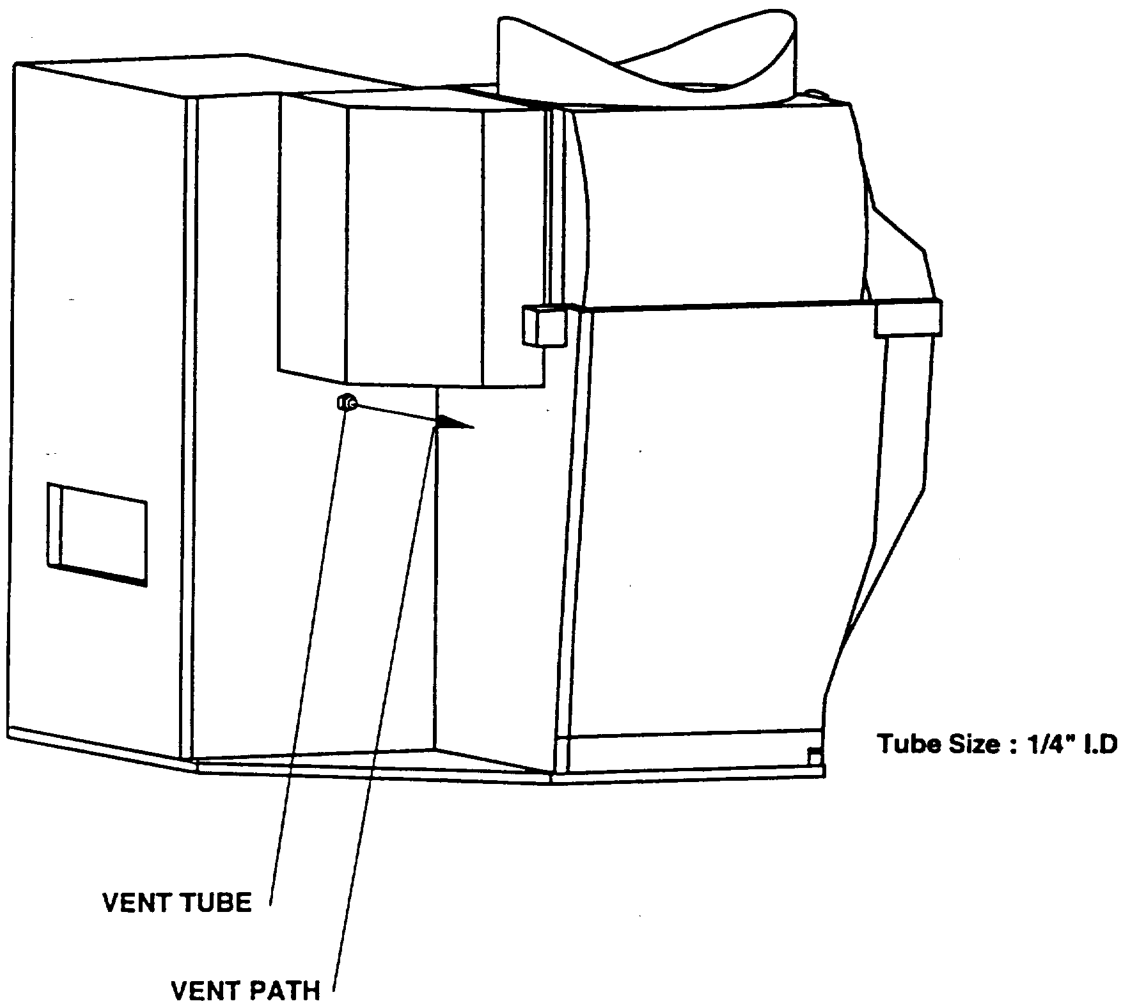


Figure 8. AMSU-A2 Vent Path

2.2.2.2 ***Procured parts***. All procured parts shall be receiving inspected for Visibly Clean condition. Parts not meeting this criterion shall be marked for cleaning to Visibly Clean condition (per Level A) prior to use.

All subcontracted items shall be specified to be Visibly Clean and bagged prior to shipment. All subcontracted items shall be receiving inspected for Visibly Clean condition. Subcontracted items not meeting this criterion shall be marked for cleaning to Visibly Clean condition (per Level A) prior to use.

2.2.2.3 ***Cleaning prior to assembly***. Parts/items marked for cleaning prior to use shall be cleaned in accordance with Level A. Vacuuming and wiping are the preferred particulate cleaning techniques. Any blowing operation should be performed away from the immediate assembly area, and high purity gaseous nitrogen (GN_2) should be used. All other parts/items shall be used directly from storage bags.

Circuit cards shall be cleaned in accordance with Level A after soldering to achieve a Visibly Clean condition. Circuit cards shall be stored in conductive shielding bags/boxes (non-shedding and low outgassing) in accordance with standard STD-2454. Coated cards are cured in accordance with the requirements of NASA 1124 to ensure meeting the materials outgassing (TML and CVCM) requirements.

2.2.2.4 *Assembly operation*

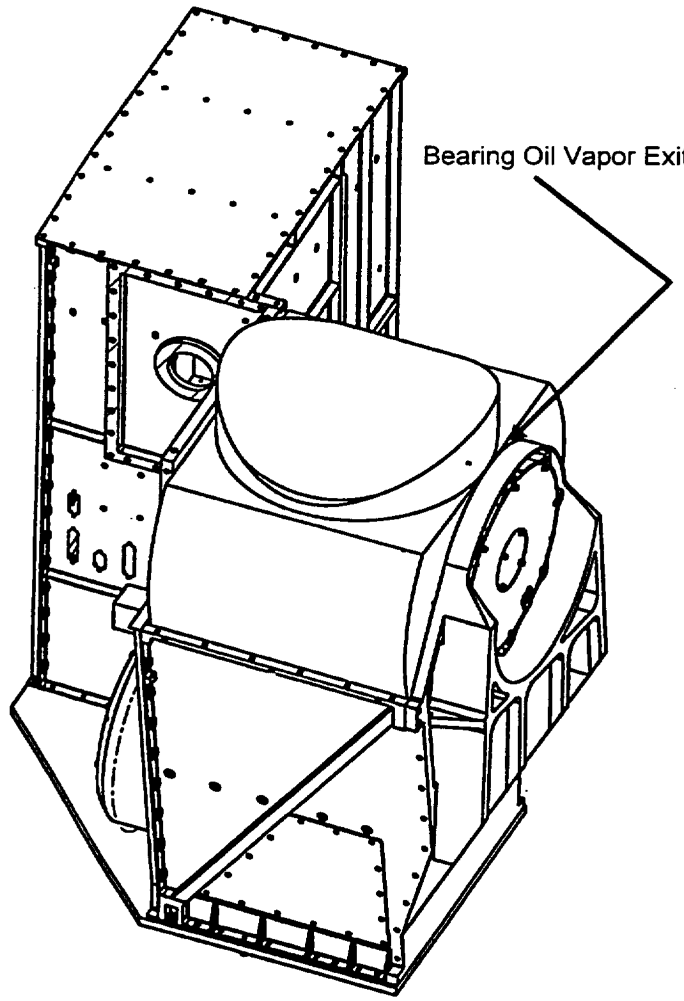


Figure 9. AMSU-A2 Bearing Lubricant Vapor Exit Area

a. All parts drilled at assembly shall be disassembled, deburred, and cleaned to a Visibly Clean level prior to permanent attachment. Exceptions require specific written approval from M & P Engineering.

b. Any debris produced during assembly operations shall be prevented from reaching any area where it cannot be completely removed. Existing joints, recesses, etc. in the area will be covered, and simultaneous vacuuming or wiping must be employed as necessary to achieve this requirement. Assembly debris must not be allowed to accumulate and will be removed immediately after every operation.

2.2.2.5 ***Cleaning after assembly***. All assemblies shall be cleaned to a Visibly Clean condition in accordance with Level A after assembly and prior to presentation for inspection. Vacuuming and wiping are the preferred particulate cleaning techniques. Any blowing operation should be performed away from the immediate assembly area and high purity gaseous nitrogen (GN_2) should be used. All assembly inspection shall include inspection for Visibly Clean condition.

2.2.2.6 *Cleaning cables and connectors*

a. **Cables:** After fabrication and checkout, cables shall be cleaned to achieve a Visibly Clean condition and to remove surface volatile condensable materials prior to bakeout in accordance with Level B. After inspection and bagging, cable bake-out can take place at any time prior to use.

b. **Electrical connectors:** Prior to final mating, electrical connectors (including motherboard and other in-line connectors) shall be cleaned in accordance with Level A to achieve a Visibly Clean condition.

2.2.2.7 *Cleaning external thermal control surfaces*. After all testing and just prior to placing the instrument into the shipping container, external thermal control surfaces shall be cleaned to achieve MIL-STD-1246, Level 600A surface cleanliness in accordance with Level C. Second-surface mirrors and silvered Teflon will be cleaned as specified below:

a. **Second-Surface Mirrors:** Second-surface mirrors will be cleaned and verified in accordance with AE-26676, using materials and equipment described in AE-25367.

b. **Silvered Teflon:** Silvered Teflon surfaces will be cleaned in accordance with AE-26675 to remove surface contaminants.

Goldized surfaces will be cleaned in accordance with AE-26677, Level A for METSAT and Level C for EOS.

2.2.2.8 *Cleaning thermal control blankets*. One set of Thermal Control Blankets will be fabricated specifically for use in thermal-vacuum testing; a separate flight set of Thermal Control Blankets will be fabricated for shipment with the Instrument. The flight set of Thermal Control Blankets shall be vacuumed clean and then wiped clean to achieve a Visibly Clean condition and to remove surface volatile condensable materials prior to their bakeout (in accordance with Level B).

Thermal Control Blankets are packaged separately and shipped along with the Instrument in its shipping container.

2.2.2.9 *Cleaning ground support equipment (GSE)*. Ground Support Equipment shall be vacuumed and cleaned to a Visibly Clean condition (Level A) before being moved into the Class 100,000 manufacturing area. Connectors that interface directly with the instrument must be cleaned to achieve a Visibly Clean condition (Level A) before each mating.

Special test cables used within the Thermal-Vacuum chambers shall be cleaned to achieve a Visibly Clean condition and to remove surface volatile condensable materials (Level B) and then baked-out as described in 2.2.4.1, prior to the first exposure to vacuum in the thermal/vacuum test chamber.

2.2.2.10 *Recleaning instrument hardware after testing outside Class 100,000 area*. Instrument hardware that has been moved out of the Class 100,000 area for environmental or antenna range testing shall be inspected and recleaned as required to achieve a Visibly Clean condition (Level A) upon return.

2.2.3 *Covering*

2.2.3.1 *Bagging parts.* Cleanliness preservation will be maintained by storing parts in sealed, non-shedding, low outgassing (non-plasticized) approved ESD protective bags or containers prior to assembly operations. Bags and containers shall be visually inspected for contamination, and, if necessary, shall be cleaned by wiping with suitable cleaning agents or flushed with high purity dry nitrogen to remove interior surface contaminants.

2.2.3.2 *Protecting assemblies*. Clean subassemblies are to be protected from particulate fallout and non-volatile residue (NVR) while waiting further assembly operations. Protective materials shall be installed over cleaned hardware to maintain cleanliness and prevent accumulation of contamination during the assembly phase. Protective materials shall completely cover hardware and should be heat sealed whenever feasible after placement of the hardware into the bag. Only approved ESD protective materials shall be used.

2.2.3.3 ***Protective covers***

a. Waveguide fabrication and assembly drawings for the waveguide hardware shall have the requirement that after final cleaning and prior to shipment all open ports shall be capped with cleaned close-fitting, non-contaminating removable covers. This covering shall be maintained over the ports at all times unless the waveguide is being tested or installed

b. The feedhorn is to be protected from contamination by placing it in a clean non-contaminating bag. A close-fitting, non-contaminating removable cover shall be installed over the feedhorn opening after the antenna is installed in the antenna subassembly. The cover is to remain over the opening at all times unless the feedhorn is being tested or installed.

2.2.3.4 ***Preparations for storage and transport.*** All flight hardware must be protected from contamination during storage or transportation by being contained in clean, closed ESD bags or containers such that cleanliness conditions are preserved. Prior to placing the hardware into the shipping container, all interior surfaces of this container shall be cleaned in accordance with AE-26497 to cleanliness Level A and verified in accordance with 2.3.3, herein.

a. All thermal control surfaces shall be covered with a noncontaminating, nondegrading protective cover.

b. The shipping container used for transport of the hardware will be constructed from noncontaminating materials.

c. The unit shall be double bagged with a protective cover made of nonshedding, low outgassing ESD material prior to storage and when installed into shipping container.

d. The shipping containers shall provide an external purge attachment/valve.

2.2.3.5 ***Shipping container description.*** The EOS/METSAT AMSU-A shipping containers are constructed from noncontaminating materials and are cleaned in accordance with AE-26497 to cleanliness Level A immediately before use. In addition, the Instrument is doubled bagged with a protective cover made of non-shedding, low-outgassing ESD material when being placed into the shipping container.

2.2.4 ***Bakeout and preparation for thermal-vacuum test***

2.2.4.1 ***Bakeout.*** Bakeout is used on specific components on the EOS/METSAT AMSU-A, prior to integration into the instrument, to most-efficiently drive off volatile condensable materials. Thermal blankets, wiring harnesses, circuit boards, and second surface mirror panels are exposed to higher-than-flight temperatures in a vacuum so that, when the instrument is subsequently in thermal-vacuum testing, the outgassing from these components will be minimal.

All bakeouts are preceded by cleaning in accordance with Level B to remove surface volatile condensable materials. The bakeout chamber shall be cleaned to remove surface contaminants (Level B), prior to its first bakeout on the EOS/METSAT AMSU-A equipment. Recleaning is required if the chamber is subsequently contaminated by other usage.

The empty bakeout chamber shall be pumped down until it reaches a stable pressure at room temperature to establish a reference internal pressure. See point A on Figure 10. Then, the chamber is returned to ambient pressure, opened, and the component to be baked out is installed (all protective materials are removed and the component is placed on a visibly clean metal sheet). The chamber is then pumped down until it reaches a stable pressure at room temperature, and a second reference internal pressure is established. See point B on Figure 10.

At that point, the internal temperature is raised to the bakeout temperature for the specific component. The pressure is monitored and plotted as shown between points C and D on Figure 10. Bakeout shall continue until the pressure change for the last 25 percent of the time since peak pressure (at bakeout temperature) is less than 5 percent of the total pressure decrease. At this point, essentially all of the volatile materials have been driven off and the bakeout is complete. The temperature is reduced to room temperature, resulting in a decrease in pressure. See point E on Figure 10. The chamber pressure is then returned to room ambient and the component removed and placed in a protective bag.

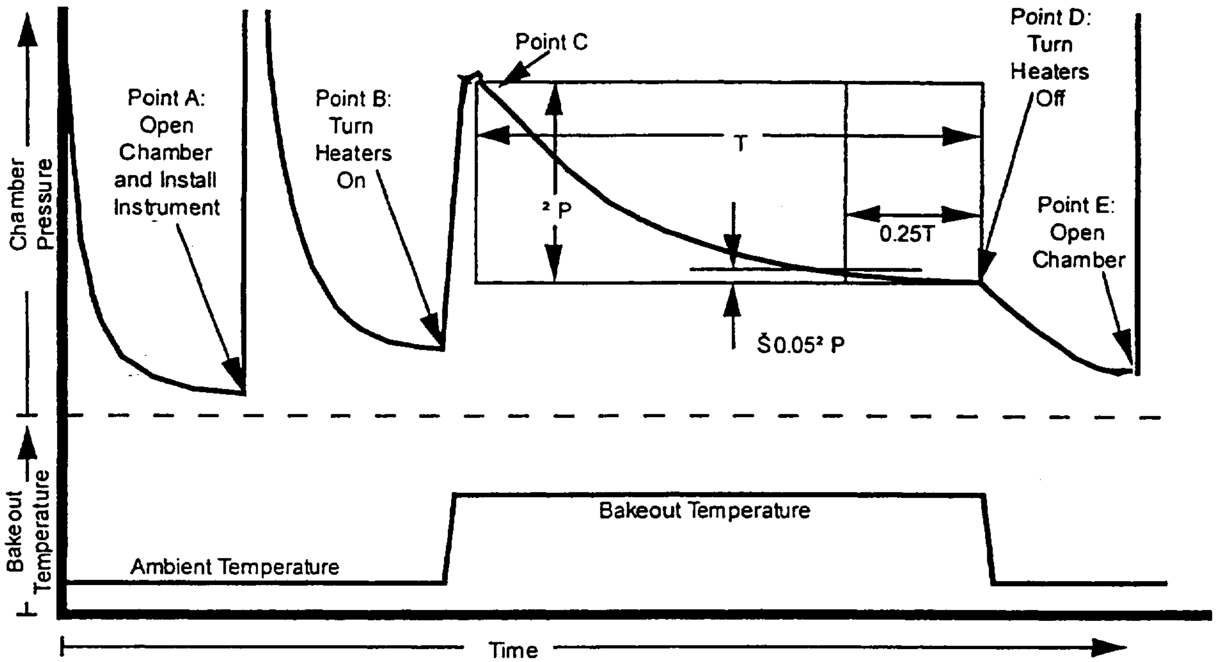


Figure 10. Typical Bakeout Pressure Curves

2.2.4.2 *Pre-thermal vacuum test preparations and back-up plan*

2.2.4.2.1 ***Pre-thermal vacuum test preparation***. For EOS instruments, compliance with the outgassing requirements of PAR 9.3B is verified during the last hot cycle of thermal-vacuum testing. At that point in the testing, the instrument shall outgas at a rate less than or equal to 1×10^{-7} g/cm^2 -hr for 5 consecutive hours at the maximum instrument operating temperature, as measured by a temperature controlled quartz crystal microbalance (TQCM) located within the test chamber and maintained at -20 ± 2°C. The TQCM must have a representative view of the instrument. There is no specific outgassing rate defined for METSAT instruments.

To ensure that the required measurement represents instrument outgassing, and not chamber or accessory equipment outgassing, the following pre-thermal vacuum test steps will be taken:

a. Prior to thermal-vacuum testing, the interior surfaces of the chamber will be inspected and, if necessary, be cleaned using suitable cleaning agents (e.g., wipes and alcohol).

b. Any accessory equipment (TQCM, RGA, etc.) and all in-chamber cabling shall be cleaned to achieve Visibly Clean condition and to remove surface contaminants prior to pumpdown.

c. Prior to the introduction of the Instrument into the chamber (but with all other equipment and cabling present), the chamber shall be pumped down and the temperature run through a full thermal-vacuum cycle. During the hot cycle, the chamber pressure, the TQCM reading, and the RGA reading shall be recorded. If the TQCM reading is less than 1×10^{-8} grams/square centimeter/hour, the chamber is validated for the test. Otherwise, the source of the outgassing must be determined and reduced.

d. Witness plates were used on the NOAA/AMSU-A program to measure cleanliness conditions of the instrument and test chamber during testing. Data were collected from NOAA/AMSU-A tests so that a cleanliness baseline could be established for the EOS/AMSU-A program. NVR was generally well below the MIL-STD-1246, Class A, requirement if diffusion pump oil is neglected. The chamber using diffusion pumps (WC1) is being modified to use cryopumps in the future, so no difficulty is anticipated for EOS/AMSU-A to meet the NVR Class A requirement. Also, no traces of Apiezon C, the volatile AMSU-A bearing lubricant, were detected.

2.2.4.2.2 ***Back-up plan***. The major source of outgassing in the AMSU-A instrument is predicted to be the bearing lubricant. Calculations show that the lubricant outgassing flux may approach the EOS PAR limit of 2.8×10^{-11} g/cm^2-s (1×10^{-7} g/cm^2-hr). With this outgassing source near the PAR limit, it is prudent to try to identify the chemical characteristics of the main source of outgassing during this test. Thus, the plan is to install a Residual Gas Analyzer (RGA) and a sufficient area of witness plates (to collect outgassed materials) to provide information on outgassing material characteristics.

2.2.5 *Control over other activities*

While most of the operations on the EOS/METSAT AMSU-A take place in a Class 100,000 area, there are several critical operations that are conducted in "lesser cleaned" environments.

2.2.5.1 ***Antenna range***. A series of critical performance measurements must be conducted at the Aerojet Antenna Range, which is not a cleanliness controlled area. Hardware that leaves the Class 100,000 area for such testing shall be protected by protective material and custom covers whenever feasible. Particularly, the waveguide ports and the feedhorn opening are provided with special covers, as described in 2.2.3.3. Upon return to the Class 100,000 area, the hardware shall be recleaned (Level A) to achieve a Visibly Clean condition.

2.2.5.2 ***Environmental test laboratory***. A series of critical tests must be conducted at the environmental test laboratory, which is not a cleanliness controlled area. Hardware that leaves the Class 100,000 area for such testing shall be protected by protective material and custom covers whenever feasible. Particularly, the waveguide ports and the feedhorn opening are provided with special covers, as described in 2.2.3.3. Upon return to the Class 100,000 area, the hardware shall be recleaned (Level A) to achieve a Visibly Clean condition.

2.2.6 *Contamination training program*

Personnel working in clean areas (class 10,000 or better) will be trained by cognizant supervision. Training shall include, where applicable, the following subjects:

Donning and proper use of clean room garments/gloves

Materials/Items not allowed in clean rooms

Clean room entry instructions

General clean room practices and control

2.3 *Contamination control verification*

Verification of Contamination Control requirements defined in 2.1 is accomplished by executing the four tasks shown in the double lined boxes on Figure 11. Defining out-of-control conditions and corrective actions is covered in 2.3.5.

2.3.1 *Verifying material selection*

Materials and Processes (M&P) Control verifies the correct selection of materials through the EOS/METSAT M&P Database. This database is generated by M&P Control from drawings and parts lists submitted to Configuration Management by subsystem product teams on every subassembly (including subcontracted items).

M&P Control participates in and monitors progress of each Product Team. In this way, M&P reviews and approves all subsystem and component specifications and is cognizant of M&P selection issues at optimum stages in the development of hardware.

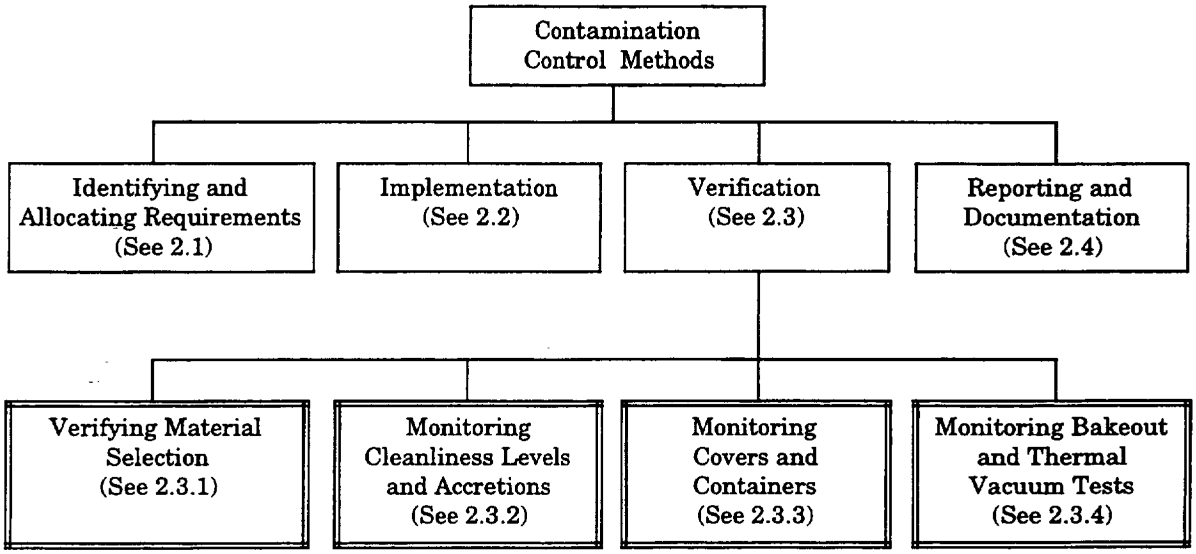


Figure 11. Contamination Control Verification Tasks

The EOS/METSAT M&P database tracks M&P type and usage, conventionality status, and approval status by subassembly (as well as other data not related strictly to M&P selection). Although maintained separately from the Configuration Management lists, this database is periodically audited by CM against those maintained by CM to ensure consistency.

The EOS/METSAT M&P database is annotated so that reports can be generated meeting the requirements of the Materials Lubricants, Processes List (CDRL 506), and the As-Built Materials List (CDRL 525). These reports are provided in hard copy and as an ASCII file on magnetic media.

Full compliance with the M&P selection requirements is achieved by having all necessary approvals for every material and process in the EOS/METSAT M&P database. The M&P selection status is reported on the monthly Performance Assurance Status Report. Waiver requests for use of out-of-date materials are handled through CDRL 202 (30 days prior to material usage).

2.3.2 *Monitoring cleanliness levels and accretions*

2.3.2.1 ***Audits***. Quality Assurance will audit the work area against all requirements of Class 100,000, including facilities, equipment, training and procedures. Quality Assurance will audit the production, inspection, and test processes on EOS/METSAT AMSU-A, including the contamination/cleanliness controls. Audits shall be conducted in accordance with PAIP Section 1.9 and 8.27.2

2.3.2.2 ***In-process cleanliness monitoring***. Quality Assurance will inspect fabricated parts, procured parts, assemblies, cables, connectors, and circuit cards (as defined in 2.2.2) after cleaning (Level A or B) for Visibly Clean conditions.

2.3.2.3 ***Final exterior surface cleanliness verification test***. Quality Assurance will inspect exterior surfaces of the completed EOS instrument, after cleaning (Level C) for MIL-STD-1246, Level 600A surface cleanliness. METSAT instruments shall be Level A, except thermal control surfaces shall be Level C.

2.3.2.4 ***Measuring GSE***. Quality Assurance will inspect Ground Support Equipment (including cables) as defined in (2.2.2.9) after cleaning (Level A or B) for Visibly Clean conditions.

2.3.3 ***Monitoring covers and containers***

Quality Assurance will inspect covers and containers for visible contamination when submitted with parts and assemblies. Visible contamination shall be cause for recleaning item and cover/container.

2.3.4 ***Monitoring bakeout and thermal vacuum tests***

2.3.4.1 ***Bakeouts***. Quality Assurance will review bakeout data as defined in 2.2.4.1 for compliance with procedure.

2.3.4.2 ***Thermal vacuum test setup***. Contamination Control will review the Thermal/Vacuum Test Setup defined in 2.2.4.2 for compliance with procedure.

2.3.4.3 ***Last thermal-vacuum cycle outgassing test***. In addition to Quality Assurance, Contamination Control will witness the outgassing test portion of the Thermal-Vacuum test. Contamination Control will monitor the TQCM and RGA measurements and shall recommend to the SEIT PT leader any corrective action, extension of test, or other response to real-time indications. Contamination Control is responsible for ensuring that the required witnesses are satisfied that the Instrument has met the outgassing requirement.

2.3.5 ***Defining out-of-control conditions and corrective actions***

There are two final quantitative requirements on the EOS instrument: external surface cleanliness and outgassing. Compliance with the requirement to meet MIL-STD-1246, Level 600A surface cleanliness on the external surfaces of the final configuration should be straightforward. If, for any reason, the instrument fails to meet this inspection criterion when presented after final cleaning and just prior to placing the instrument in the shipping container, the Instrument shall be recleaned.

All analyses and predictions indicate that compliance with the 1×10^{-7} g/cm^2-hr outgassing requirement will also be straightforward. However, if the TQCM data indicate that the instrument fails in the last hot cycle of the thermal-vacuum test, corrective action is not so easy. In that case, and before the last hot cycle is terminated, the RGA data will be studied to determine if the outgassing source is the bearing lubrication. If the source is the bearing, the test will be terminated and discussions held with NASA, since changing this lubricant is not a desirable option. If the RGA data indicate that the source is not the bearing, and if the outgassing rate only marginally exceeds specification limits, Contamination Control may recommend to extend the hot cycle to take advantage of further bakeout.

The METSAT instrument has no similar requirement. It is cleaned in accordance with 2.2.2.5 for the assembly and 2.2.2.7 for the thermal control surfaces, and is inspected in accordance with 2.3.2.3.

2.4 ***Contamination control reporting and documentation***

2.4.1 ***The contamination control plan***

This Contamination Control Plan provides the guidance to the program for all Contamination Control issues.

2.4.2 ***Related CDRL***

The combining of M&P and Contamination Control in the EOS/METSAT AMSU-A Program provides tight integration between related issues and coordinates the efforts under PAIP Section 6, CDRL 506, and PAIP Section 9.

2.4.3 ***Performance assurance status report***

Contamination Control status is reported monthly in the Performance Assurance Status Report, which is submitted as part of the monthly Progress Report.

SECTION 3

CONTAMINATION CONTROL FLOWCHART AND SCHEDULES

3.1 *Contamination control flowchart*

The top-level fabrication and assembly flow of the A1 module of the EOS/AMSU-A hardware is shown in Figure 12 (foldout). This figure is a simplified version of the detailed fabrication and assembly flow charts (referred to at Aerojet as Integrated Manufacturing, Inspection, and Test Plans–IMITP) provided in Appendix B of the Fabrication and Assembly Plan (CDRL 023). The fabrication and assembly flow process for the A2 module is similar but simpler.

Figure 12 has been annotated to show the implementation steps of cleaning, covering, and bakeout (described in 2.2) and the verification steps of inspection and measurement (described in 2.3). These steps will be coded into the detailed IMITP prior to its final submittal.

3.1.1 *Description of fabrication and assembly operations*

Physical construction starts with the fabrication of machined parts for the Antenna Subassembly, the basis for the Antenna Assembly. The Feedhorn Assemblies are fabricated and matched to their respective Diplexer/Multiplexer by an outside source, received at Aerojet, and installed into the Antenna Assembly. The Drive Assembly Housings are fabricated and inspected, the motors and resolvers are installed to make up the Drive Assemblies, and then installed in the Antenna Assembly. The Reflector Assemblies for the A1 Module are fabricated, inspected, and mounted in the Antenna Assembly. The reflector for the A2 Module is procured from an outside source and installed upon receipt. The completed Antenna Assembly is Acceptance Tested to its Subsystem Specification utilizing the appropriate Test Procedure as defined in the Performance Verification Plan, CDRL 022. After testing and accepting the Antenna Assembly, the Core Assemblies (warmload cores, temperature sensors, and enclosures) are installed, completing the Antenna Assembly. The Antenna Assembly provides the structure for the installation of the other major subsystems.

The Wire Harnesses are fabricated and installed in the structure. The A1-1 RF Shelf is assembled, functionally tested, and installed in the structure. The Phase-Locked Oscillator, a buy item on NOAA/AMSU-A, is fabricated, assembled, tested, and inspected. The Circuit Card Assemblies are assembled, checked-out individually, and temporarily inserted into their Card Cages, and functionally tested as the Signal Processor Subassembly. Next, the A1-2 RF Shelf is assembled, functionally tested, and installed in the structure. The checked-out Signal Processor is temporarily installed in the structure, followed by the installation of the subcontracted DC/DC Converter. Finally, the Preamp Detector Assembly is fabricated, assembled, checked out, and temporarily installed.

With the instrument now functionally complete, an intensive battery of tests is performed (as defined in the Performance Verification Plan, CDRL 022). Upon successful completion of these tests, the instruments are partially disassembled. The Panels are removed for the installation of mirrors into Mirror Panel Assemblies. The Circuit Card Assemblies are removed from the Signal Processor and the Preamp Detector Assemblies for conformal coating and final acceptance.

The instrument is then reassembled in its final configuration, inspected, and submitted for Acceptance Testing, which includes environmental testing and instrument calibration. After Acceptance Testing, the instruments are cleaned and inspected. Each finished instrument is then installed in its Shipping Container along with its separately fabricated Insulation Blanket, inspected, and delivered to the Spacecraft Integrator.

3.1.2 *Identification of critical fabrication and assembly activities*

Fabrication and assembly activities are performed in a Class 100,000 environment, as described in 3.2. Activities that are performed in less controlled environments are not contamination-critical, and recleaning of hardware upon re-entering the Class 100,000 environment is discussed in 2.2.

3.1.3 *Identification of all cleaning, packaging, and bakeouts*

Cleaning, packaging, and bakeouts are identified on Figure 12, and discussed in detail in 2.2.

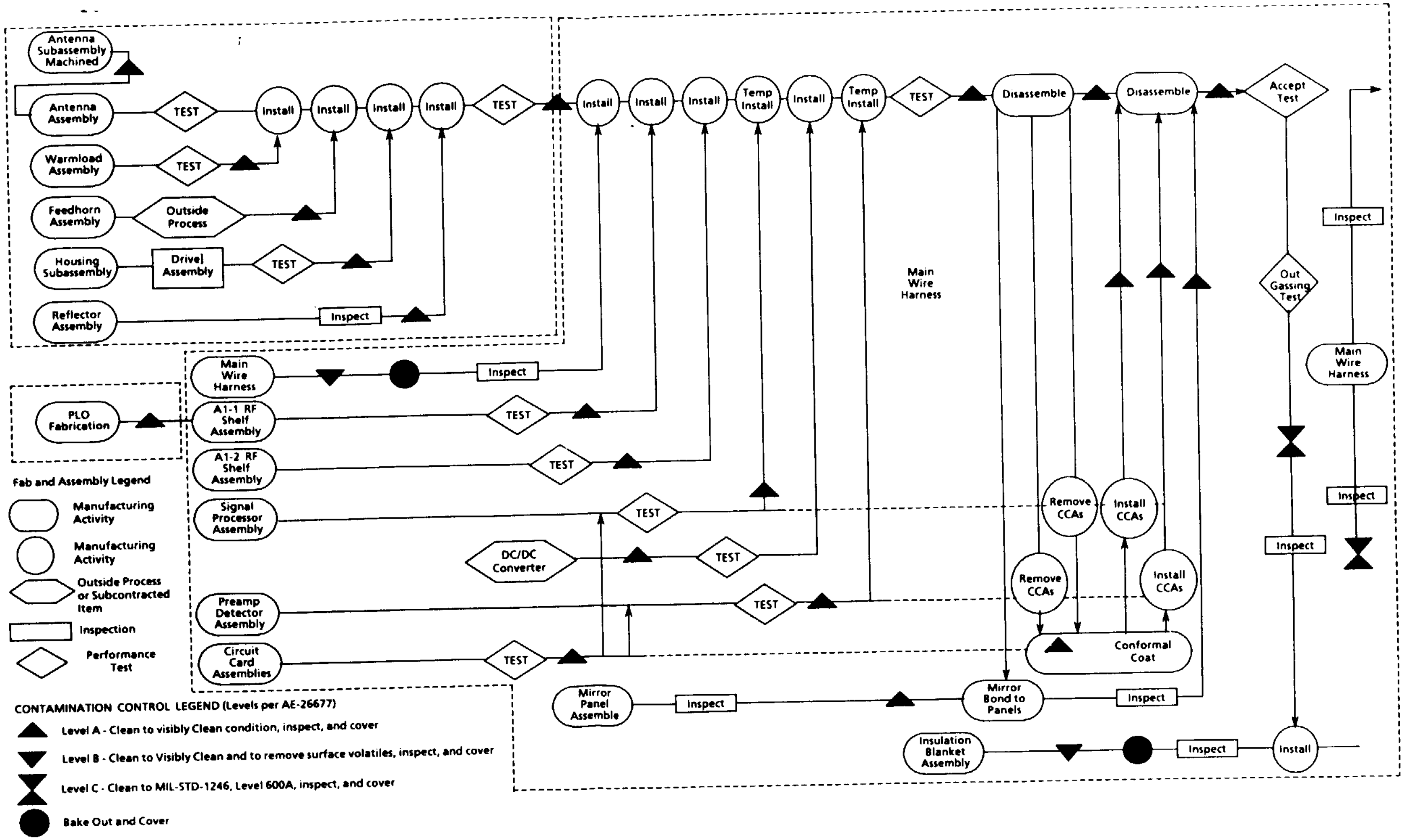


Figure 12. Top-level fabrication and assembly flow of the EOS/AMSU-A1 hardware, showing Contamination Control Implementation and Verification Steps

3.1.4 *Identification of all controls over contaminants, temperature, and humidity*

The Class 100,000 environment is completely controlled to meet the requirements of FED-STD-209, including control of contaminants, temperature, and humidity.

3.2 *Identification of the sites of the operations*

It is Aerojet's goal to be a superior manufacturing company in all areas where we choose to compete. To this end, Aerojet's manufacturing organization has just gone through a major ($14 million) facility and equipment upgrade, to provide the basis for the ongoing production of high-quality, high-reliability products in a much shorter time. The major items incorporated in this change are:

a. Class 100,000 modernized manufacturing facility (Building 57)

b. Colocation of manufacturing commodity line

c. Availability of a new, semiautomatic circuit card assembly facility

d. Development of Integrated Product Teams

e. Incorporation of MRP II to plan, track, and control material and production

f. Expansion of environmental test capability, including another new, large thermal-vacuum chamber (Building 183)

3.2.1 *EOS/METSAT production facilities*

EOS/METSAT AMSU-A will be produced at Aerojet's Azusa Operation, shown in Figure 13. The production facilities at the Azusa location are a complex of buildings, with each having its own function. The production and test operations on the EOS/METSAT AMSU-A program will be performed at the following sites:

Building 57 – Building 57, shown in Figure 14, is scheduled to be the center of all manufacturing activities for EOS/METSAT AMSU-A and all other millimeter wave sensor production. It contains the machine shop, the circuit card assembly fabrication, box and subsystem assembly, the system level integration and in-process test facilities, as well as the antenna range test facility.

Building 183 – All environmental stress testing, such as vibration and thermal/vacuum conditioning, and final acceptance testing will take place in the Building 183 Environmental Laboratories. A detailed layout and description of test areas of this facility is provided in Section 7 of the Performance Verification Plan (CDRL 022).

Building 200 – The manufacture of insulation blankets and mirror panels will be moved to a renovated facility in Building 200, previously used to assemble microelectronic circuits.

Building 168 – Building 168 does not contain any production facility, but a newly refurbished section in this building can be used as a special facility for long-term instrument storage.

3.2.2 *Production facility upgrade*

Building 57 has received the bulk of the modernization upgrade effort at Aerojet. The production facility (shown in Figure 14) has been modernized with a complete circuit card assembly line consisting of up-to-date processing equipment, and utilizing the latest cleaning technology in eliminating Ozone Depleting Chemicals (ODC).

The upgraded Millimeter Wave Facility in Building 57 is shown in detail in Figure 15. The inclusion of a screen room and an electrically operated 1/2 ton crane within this facility enables the EOS/METSAT AMSU-A to be completely assembled, tested (except for the environmental testing conducted in Building 183), and packaged in its shipping containers without ever leaving the facility.

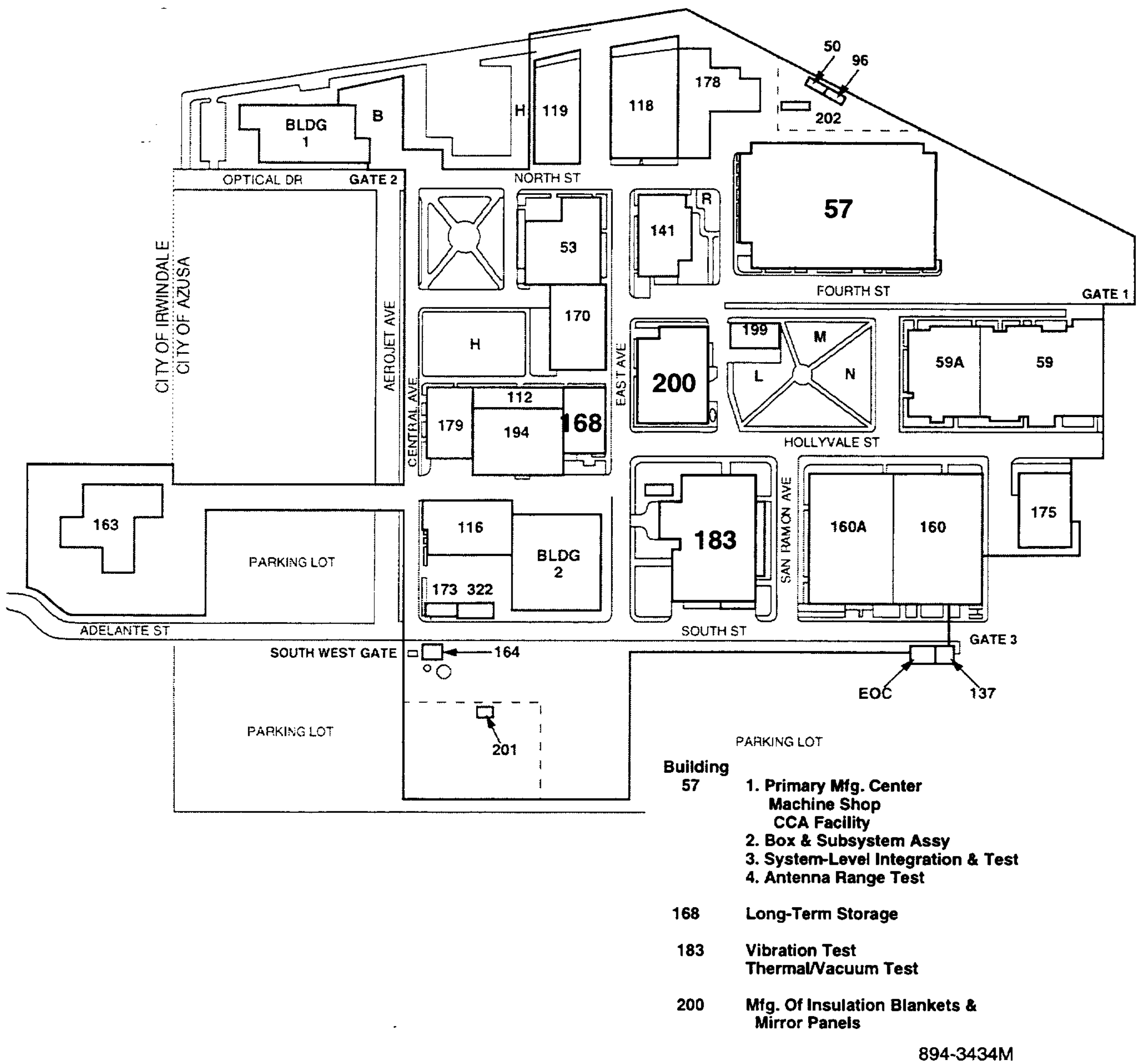


Figure 13. Aerojet Azusa Operations (Showing Sites of EOS/METSAT AMSU-A Manufacturing)

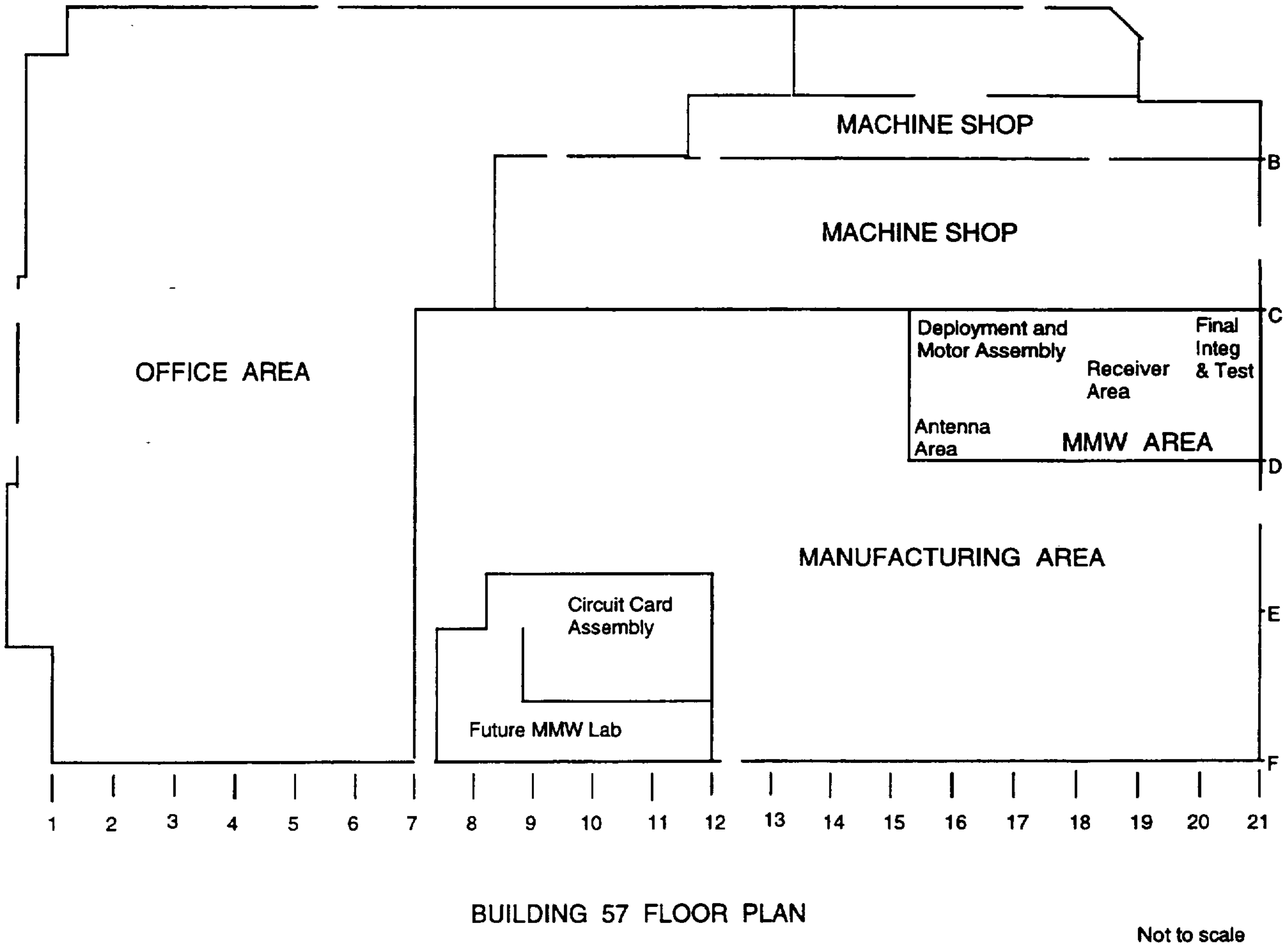


Figure 14. Aerojet Azusa Building 57 (Showing Sites of EOS/METSAT AMSU-A Manufacturing)

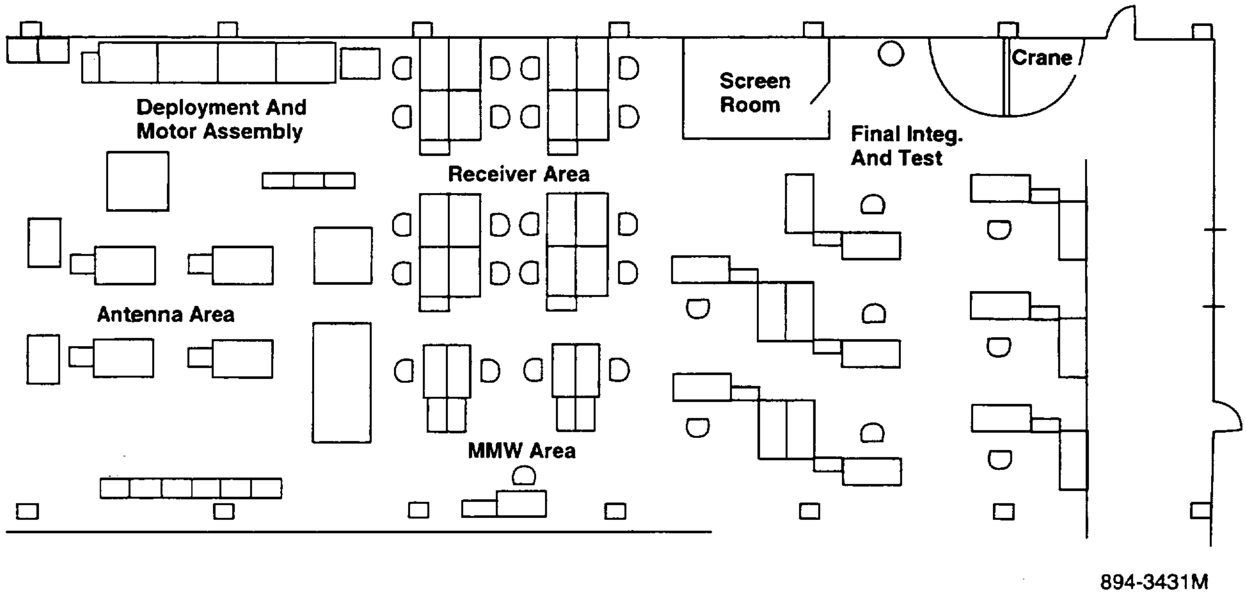


Figure 15. Details of Building 57 (Upgraded Millimeter Wave Area)

SECTION 4

NOTES

4.1 *Changes*

The outside margins of this document have been marked to indicate where modifications, deletions, or additions have been made since the previous issue. This is done solely as a convenience to users, who are cautioned to evaluate the requirements of this document based on the entire content as written, regardless of the marginal notations and relationship to the previous issue.

APPENDIX

NASA LETTER

10. APPENDIX

10.1 *Scope.* This appendix contains the NASA letter from 723 to 313/Head, Materials Assurance Office subject: Study of Lubrication Outgassing Amounts from the Earth Observing System/Advanced Microwave Sounding Unit (EOS/AMSU-A) Mechanisms

National Aeronautics and
Space Administration
Goddard Space Flight Center
Greenbelt, MD 20771

723 November 2, 1995

TO: 313/Head, Materials Assurance Office

FROM: 723.3/Claudia Woods

SUBJECT: Study of Lubrication Outgassing Amounts from the Earth Observing System/Advanced Microwave Sounding Unit (EOS/AMSU-A) Mechanisms

REF:

(a) Memo from D. W. Howell/Gencorp., Aerojet, to Mark Domen/Code 422, dtd. 10/03/93. Subject: Bearing Lubrication Contamination Analysis

(b) Memo from L. Santos and R. J. Krylo/Gencorp., Aerojet, to D. W. Howell/Gencorp., Aerojet, dtd. 10/02/93. Subject: Contamination Impact from Apiezon C Oil on EOS/AMSU-A Instruments

(c) Memo from John Scialdone/Code 422, dtd. 04/25/95. Subject: EOS-PM Bearing Lubricant Analysis: Apiezon-C with 5% Lead Napthanate

(d) Salmon, Warren A. And Apt., Charles M. Subject: A Lubrication System for Space Vehicles, Automative Engineering Congress, Detriot, MI, dtd. 01/14-18/63

(e) Gardos, Michael N. Subject: Labyrinth Sealing of Aerospace Mechanisms Theory and practice, ASLE Transactions, Vol. 17, 4, pg. 237-250, 1973

The same AMSU instrument flown on the Television Infrared Observation Satellite (TIROS) project is planned to be used on the upcoming EOS PM mission. As EOS has more strict limits than did TIROS on contamination products, there is a concern that the Apiezon-C lubricant outgassing from the bearing cartridges will exceed the contamination requirements. In preparation for a contamination study, this evaluation estimates the rate of Apiezon-C outgassing from the bearing cartridges based on molecular flow and labyrinth sealing theory.

Figures 1 and 2 (enclosed) show the lubricant escape paths for the AMSU A1 and A2 instrument drive assemblies respectively. Also shown are the relevant dimensions.

For both drive assemblies the side of the bearing pair not shown is surrounded by a sealed enclosure from which no lubricant will escape. The EOS/AMSU mechanism will have two A1 instruments and one A2 instrument.

Each drive assembly has two devices for reducing molecular flow out of the bearing. The first is a bearing shield which, though it does not provide a labyrinth path, still reduces the area over which molecular flow can occur out of the bearing. The second is an annular labyrinth path created between the dust shield and the bearing clamp. The conductances through the two paths are combined using a series sum such that

$$1/W_{Total} = 1/W_1 + 1/W_2 \quad ; \text{ where F is oil vapor conductance}$$

The conductance through the bearing shields is calculated simply using the Langmuir Equation, a model of free-surface evaporation in high vacuum based on the kinetic theory of gases:

$$W = 0.0583\, P\, (M/T)^{.5}\, A$$

where:
- W - oil loss rate (grams/second)
- P - oil vapor pressure at temperature T (torr)
- M - Molecular weight of oil
- T - Temperature (Kelvin)
- A - Area of aperture (cm^2)

The flow through the labyrinth path is calculated using the same Langmuir Equation modified by a reduction factor which is based on the length to radial gap ratio. Salmon and Apt (Reference d) used a Monte Carlo technique to generate the random walk of molecules through various length to radial gap ratio paths and established a curve of reduction factor vs. length/gap up to a length/gap of 16. Beyond a ratio of 16, the Monte Carlo technique becomes difficult to use, but they came up with a calculation which matches well with the Monte Carlo technique curve beyond the ratio of 16. None of the labyrinths in the AMSU mechanisms have a length/gap ratio greater than 4, so the Salmon and Apt curve from Reference d was used to obtain the reduction factor. This curve is reproduced in Figure 3. Reference e discusses a comparison of experimental data with various outgassing estimation methods and concludes that the Monte Carlo corrected data of Salmon and Apt closely bracket the experimental values and are slightly more conservative (higher values) than estimates based on the Knudsen formula.

The realistic estimate of oil vapour loss depends heavily, of course, on realistic values oil vapour pressure. The referenced memorandum from John Scialdone (Reference c) describes the testing John did on Apiezon C with 5% lead napthenate additive. Figure 4 shows the vapour pressure data for Apiezon C from John's memorandum.

Realistically, there will be a gradual reduction of the oil vapour pressure with time from the curve of Apiezon C with lead napthenate additive as the lighter constiuents of the mineral based additive carrier oil boil off first. This analysis does not account for any reduction of vapor pressure based on the boiling off of lead napthenate carrier oil.

AMSU A1

Here is a sample calculation at 40°C. Figure 5 shows the resulting conductances over a range of temperatures.

1. Outgassing of Apiezon C with lead napthenate for bearing shield alone at 40°C:

$T = 40°C = 313.15$ K
$M = 479$ grams/mole (Reference 3)
$P_{40°C} = 2.0\times10^{-7}$ torr
$RC = R1A$

Y gap $A_{maximum} = 2\pi(RC)(.038) = .0806$ inch^2 = 0.5199 cm^2

$W_{Y\,Gap\,40°C} = 7.5 \times 10^{-9}$ grams/second

X gap $A_{maximum} = \pi\,[(R1A_{max} + .013)^2 - R1A_{max}^2] = .0281$ inch^2 = .1813 cm^2

$W_{X\,Gap\,40°C} = 2.61 \times 10^{-5}$ grams/second

$W_{Bearing\,shield\,40°C} = ((1/W_{Y\,Gap\,40°C}) + (1/W_{X\,Gap\,40°C}))^{-1} = 1.94 \times 10^{-9}$ grams/second

2. Outgassing of Apiezon C with lead napthenate for labyrinth path alone at 40°C:

Radial gap: $a_{maximum} = R2B_{maximum} - R1B_{minimum} = .0275$ inch

Length: $LB_{minimum} = .045$ inch

$(LB/a)_{minimum} = 1.6$

From Figure 3: Reduction Factor (f) = 0.7

$\therefore W = 0.7(0.0583\,P\,(M/T)^{.5}\,A)$

$A_{maximum} = \pi(R2B^2_{maximum} - R1B^2_{minimum}) = .0953$ inch^2 = .6145 cm^2

T, M, and P are the same as for (1).

$W_{\text{Labyrinth path } 40^\circ C} = 6.20 \times 10^{-9}$ grams/second

$W_{\text{Total } 40^\circ C} = ((1/W_{\text{Bearing shield } 40^\circ C}) + (1/W_{\text{Labyrinth path } 40^\circ C}))^{-1} = 1.48 \times 10^{-9}$ grams/second

Figure 5 shows oil vapor loss rate versus temperature for one AMSU 1 instrument based on calculations as shown above.

The following temperature predictions at the A1 instrument bearings were given to me verbally by Stuart Glaser (Code 724). There was no nominal predicted temperature case, only a hot and cold case based on seasonal variations. The cold case predicted a minimum temperature of -7°C ± 10°C, and the temperature varies around the orbit by approximately 7°C. The hot case predicted a maximum temperature of 23°C ± 10°C, which also varies around the orbit by approximately 7°C. Since the outgassing rate is a highly nonlinear function of temperature, an average temperature cannot be used to determine the average rate. As there is no information available as to percentage of time spent at various temperatures, this analysis shall assume that one third of the life will be hot case orbits, one third an average temperature orbit, and one third cold case orbits. As stated above, I have also included a curve of outgassing rate vs. temperature (Figure 5) so that the average outgassing rate for a different temperature profile can be calculated if desired.

Loss Rate:

@ T = maximum T_{max} = 33° C	;	$w_{33} = 8.5 \times 10^{-10}$ gram/sec
@ T = maximum T_{avg} = 18° C	;	$w_{18} = 3.0 \times 10^{-10}$ gram/sec
@ T = maximum T_{min} = 3° C	;	$w_{3} = 1.0 \times 10^{-10}$ gram/sec

Average Loss Rate = $w_{avg} = 1/3(w_{33} + w_{18} + w_3) = 4.17 \times 10^{-10}$ gram/sec

Total Loss Over 1 Year (1 A1 Instrument) = $w_{avg}(3.1436 \times 10^7$ sec/year) = 0.0131 gram

Total Loss Over 5 Years (1 A1 Instrument) = 0.0655 gram

Total Loss Over 5 years (2 A1 Instruments) = 0.1311 gram

<u>AMSU A2</u>

Here is a sample calculation at 40°C. Figure 6 shows the resulting conductances over a range of temperatures.

1. Outgassing of Apiezon C with lead napthenate for bearing shield alone at 40°C:

$T = 40°C = 313.15\ K$
$M = 479$ grams/mole (Reference 3)
$P_{40°C} = 2.0 \times 10^{-7}$ torr
$RC = R1A$

Y gap $A_{maximum} = 2\pi(RC)(.042) = 0.1552\ inch^2 = 1.00\ cm^2$

$W_{Y\ Gap\ 40°C} = 1.44 \times 10^{-8}$ grams/second

X gap $A_{maximum} = \pi\ [(R1A_{max} + .015)^2 - R1A_{max}^{\ 2}] = .0561\ inch^2 = .3621\ cm^2$

$W_{X\ Gap\ 40°C} = 5.22 \times 10^{-9}$ grams/second

$W_{Bearing\ shield\ 40°C} = ((1/W_{Y\ Gap\ 40°C}) + (1/W_{X\ Gap\ 40°C}))^{-1} = 3.83 \times 10^{-9}$ grams/second

2. Outgassing of Apiezon C with lead napthenate for labyrinth path alone at 40°C:

Radial gap: $a_{maximum} = R2B_{maximum} - R1B_{minimum} = .015$ inch

Length: $LB_{minimum} = .050$ inch

$(LB/a)_{minimum} = 3.3$

From Figure 3: Reduction Factor (f) ≈ 0.5

$\therefore W = 0.5(0.0583\ P\ (M/T)^{.5}\ A)$

$A_{maximum} = \pi(R2B^2_{maximum} - R1B^2_{minimum}) = .0778\ inch^2 = .5016\ cm^2$

T, M, and P are the same as for (1).

$W_{Labyrinth\ path\ 40°C} = 3.62 \times 10^{-9}$ grams/second

$W_{Total\ 40°C} = ((1/W_{Bearing\ shield\ 40°C}) + (1/W_{Labyrinth\ path\ 40°C}))^{-1} = 1.86 \times 10^{-9}$ grams/second

Figure 6 shows oil vapor loss rate versus temperature for the AMSU 2 instrument based on calculations as shown above.

The following temperature predictions at the A2 instrument bearings were given to me verbally by Stuart Glaser (Code 724). There was no nominal predicted temperature case, only a hot and cold case based on seasonal variations. The cold case predicted a minimum temperature of 0°C ± 10°C. The hot case predicted a maximum temperature of 40°C ± 10°C. Since the outgassing rate is a highly nonlinear function of temperature, an average temperature cannot be used to determine the average rate. As there is no information available as to percentage of time spent at various temperatures, this analysis shall assume that one third of the life will be hot case orbits, one third an average temperature orbit, and one third cold case orbits. As stated above, I have also included a curve of outgassing rate vs. temperature (Figure 6) so that the average outgassing rate for a different temperature profile can be calculated if desired.

Loss Rate:

@ T = maximum T_{max} = 50° C ; $w_{50} = 3.7 \times 10^{-9}$ gram/sec
@ T = maximum T_{avg} = 30° C ; $w_{30} = 9.0 \times 10^{-10}$ gram/sec
@ T = maximum T_{min} = 10 ° C ; $w_{10} = 2.0 \text{ X } 10^{-10}$ gram/sec

Average Loss Rate = $w_{avg} = 1/3(w_{33} + w_{18} + w_{3}) = 1.6 \times 10^{-9}$ gram/sec

Total Loss Over 1 Year (A2 Instrument) = $w_{avg}(3.1436 \times 10^{7}$ sec/year) = .0503 gram

Total Loss Over 5 Years (A2 Instrument) = 0.2515 gram

Further questions can be directed to me at extension 4829.

Claudia Woods

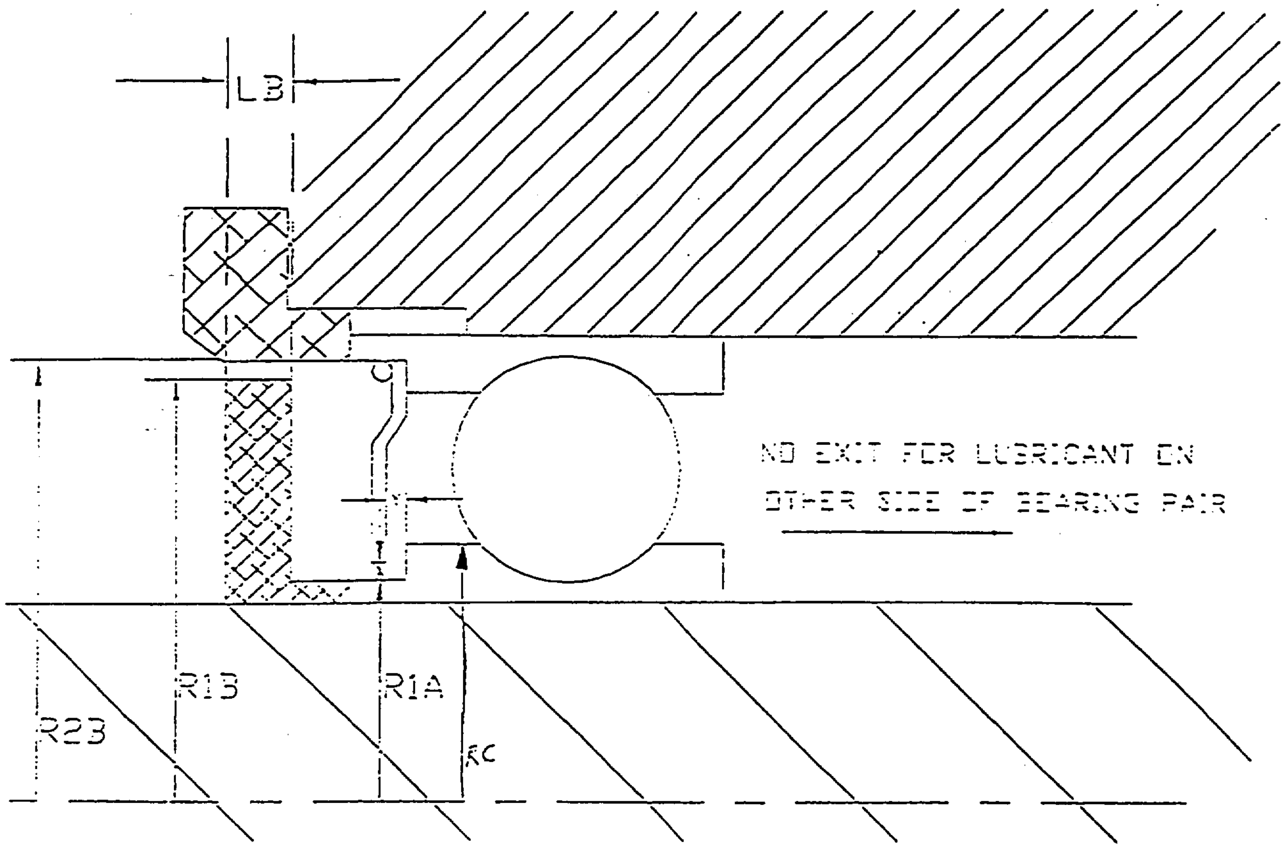
Claudia Woods

6 Enclosures

cc:
313/Mr. C. Powers
313/Mr. R. Predmore
313.1/Ms. J. Uber
720/Mr. E. Powers
720/Mr. S. Brodeur
723/Mr. K. Hinkle

7

SAI/Mr. C. DeKramer
SAI/Mr. E. Devine
SAI/Mr. J. Rockwood



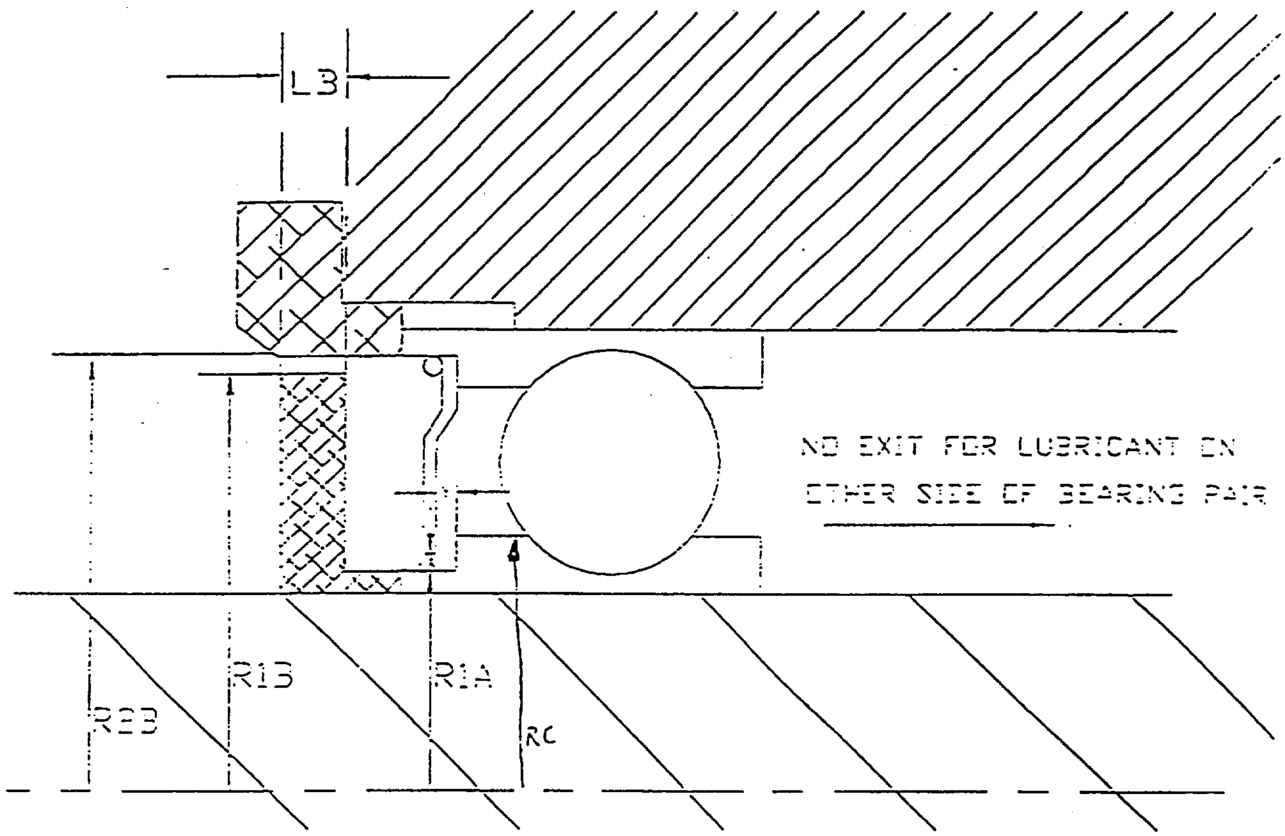
$X = \genfrac{}{}{0pt}{}{.013}{.009}$ $Y = \genfrac{}{}{0pt}{}{.038}{.022}$ $R1A = \genfrac{}{}{0pt}{}{.3375}{.3355}$ $RC \approx R1A$

$R1B = \genfrac{}{}{0pt}{}{.5400}{.5375}$ $R23 = \genfrac{}{}{0pt}{}{.565}{.560}$ $LB = \genfrac{}{}{0pt}{}{.055}{.045}$

ALL DIMENSIONS IN INCHES

AMSU A1 BEARING LUBRICANT
OUTGASSING PATH DIMENSIONS

FIGURE 1



$X = \begin{matrix}.015\\.011\end{matrix}$ $\quad Y = \begin{matrix}.042\\.026\end{matrix}$ $\quad R1A = \begin{matrix}.588\\.586\end{matrix}$ $\quad RC \approx R1A$

$R1B = \begin{matrix}.820\\.8175\end{matrix}$ $\quad R2B = \begin{matrix}.8325\\.8300\end{matrix}$ $\quad LB = \begin{matrix}.055\\.050\end{matrix}$

ALL DIMENSIONS IN INCHES

AMSU A2 BEARING LUBRICANT
OUTGASSING PATH DIMENSIONS

FIGURE 2

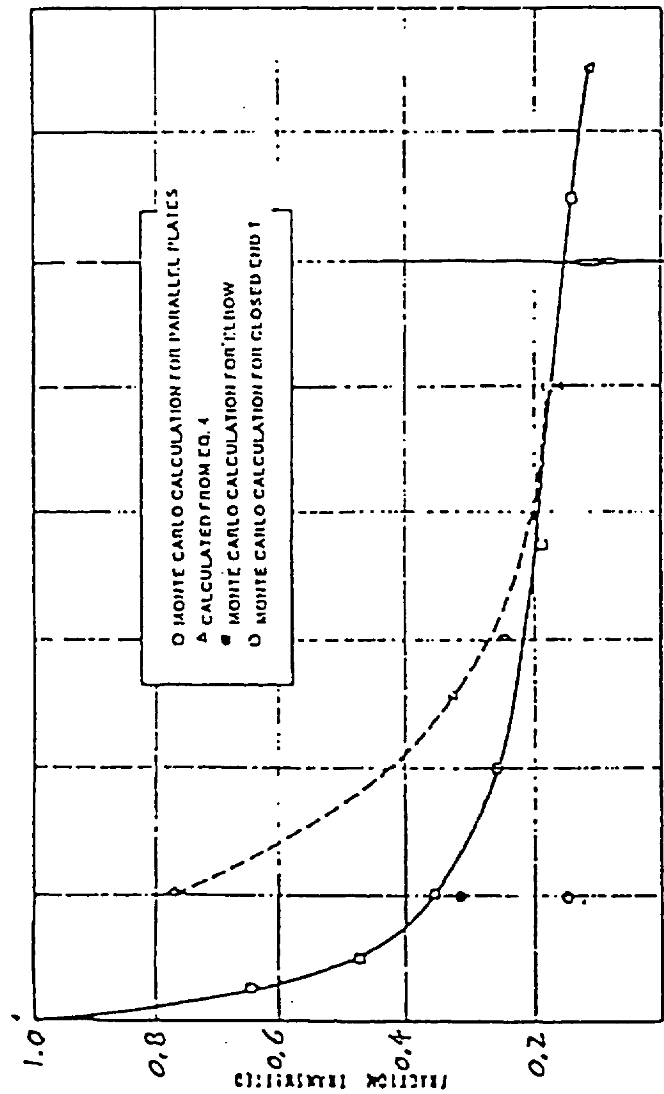


Fig. 3 - Results of Monte Carlo analysis
FROM REF. 4, FIGURE 4

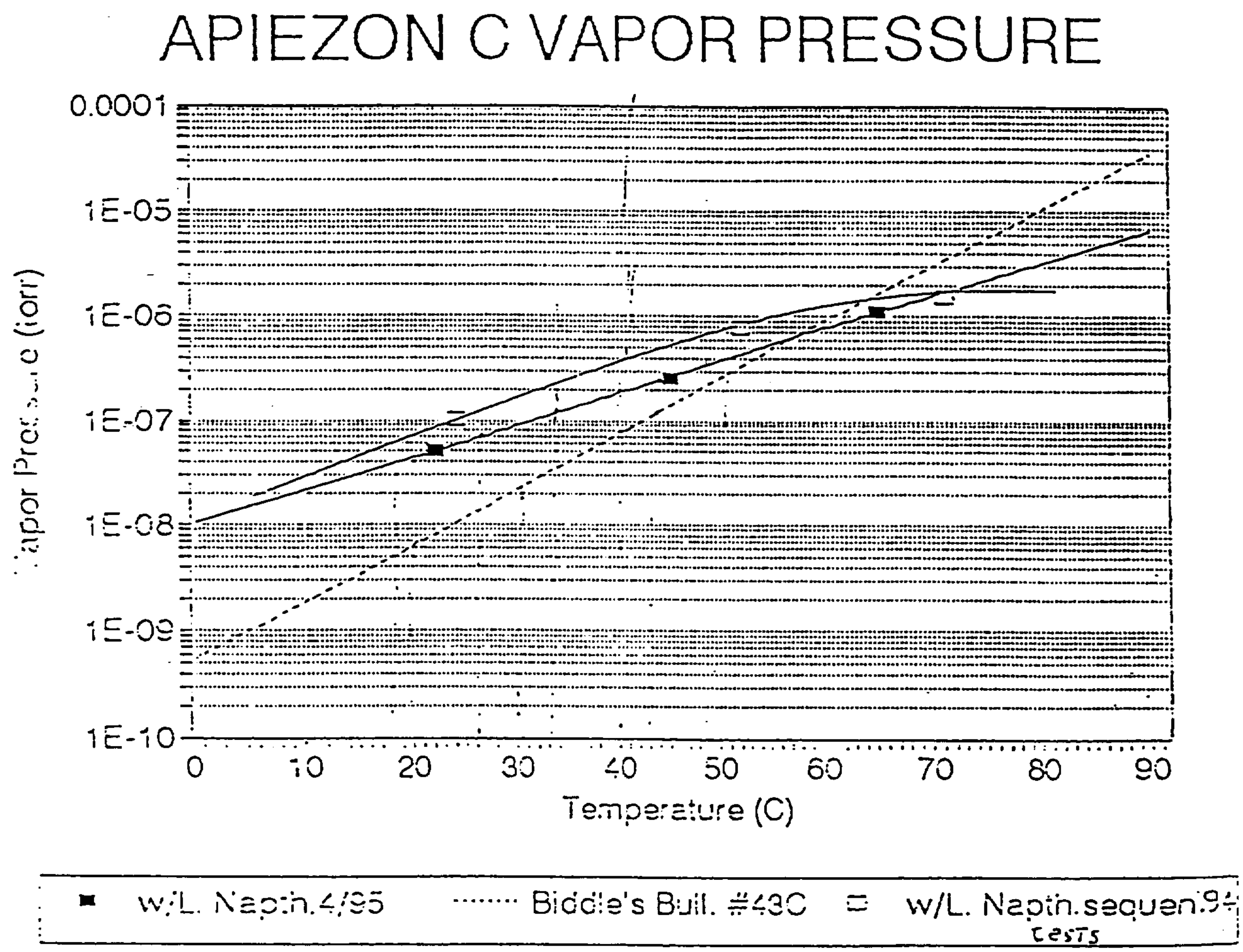


FIGURE 4 (FROM REF. 3)

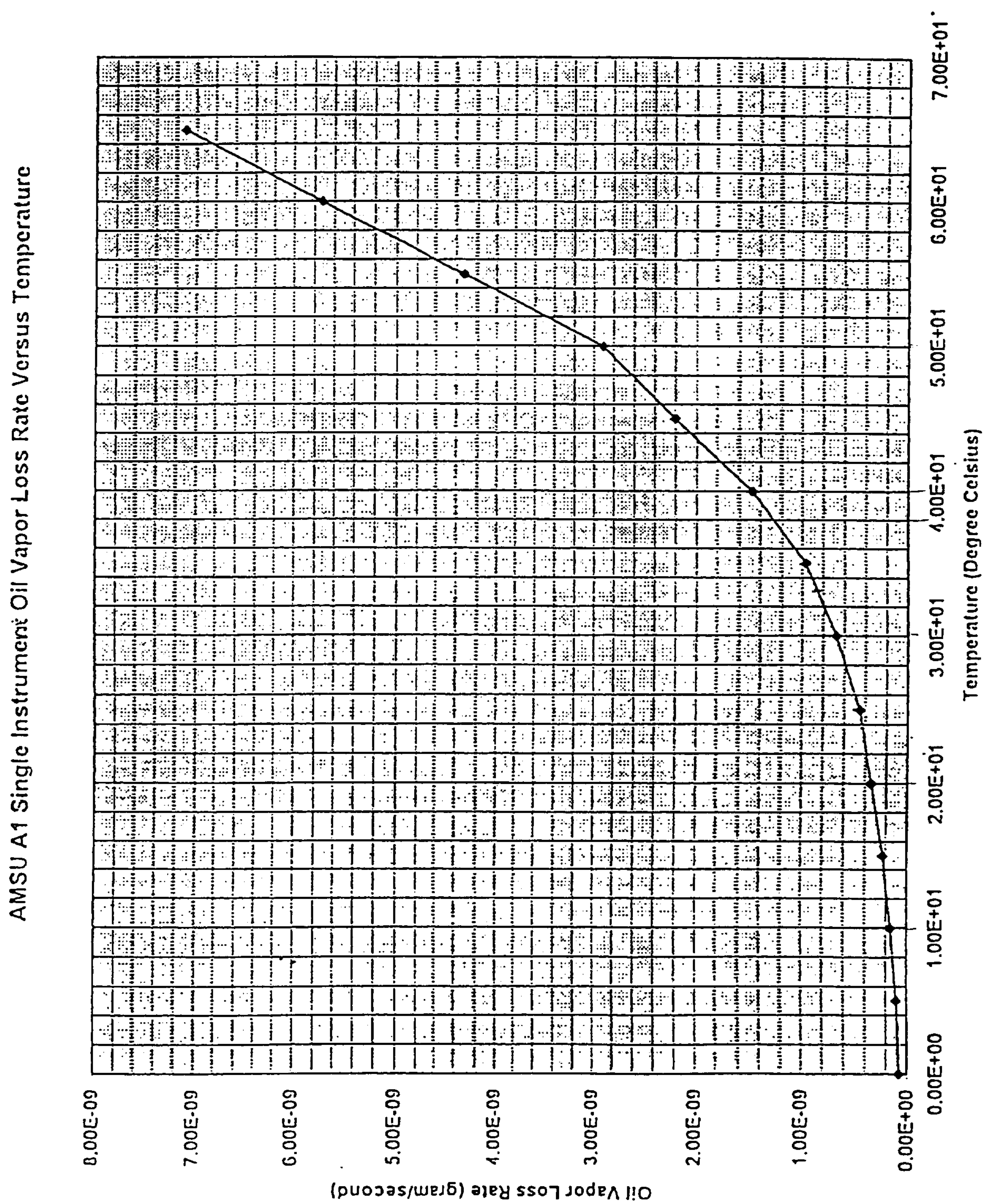

AMSU A1 Single Instrument Oil Vapor Loss Rate Versus Temperature
Oil Vapor Loss Rate (gram/second)
0.00E+00
1.00E-09
2.00E-09
3.00E-09
4.00E-09
5.00E-09
6.00E-09
7.00E-09
8.00E-09
Temperature (Degree Celsius)
0.00E+00
1.00E+01
2.00E+01
3.00E+01
4.00E+01
5.00E+01
6.00E+01
7.00E+01

FIGURE 5

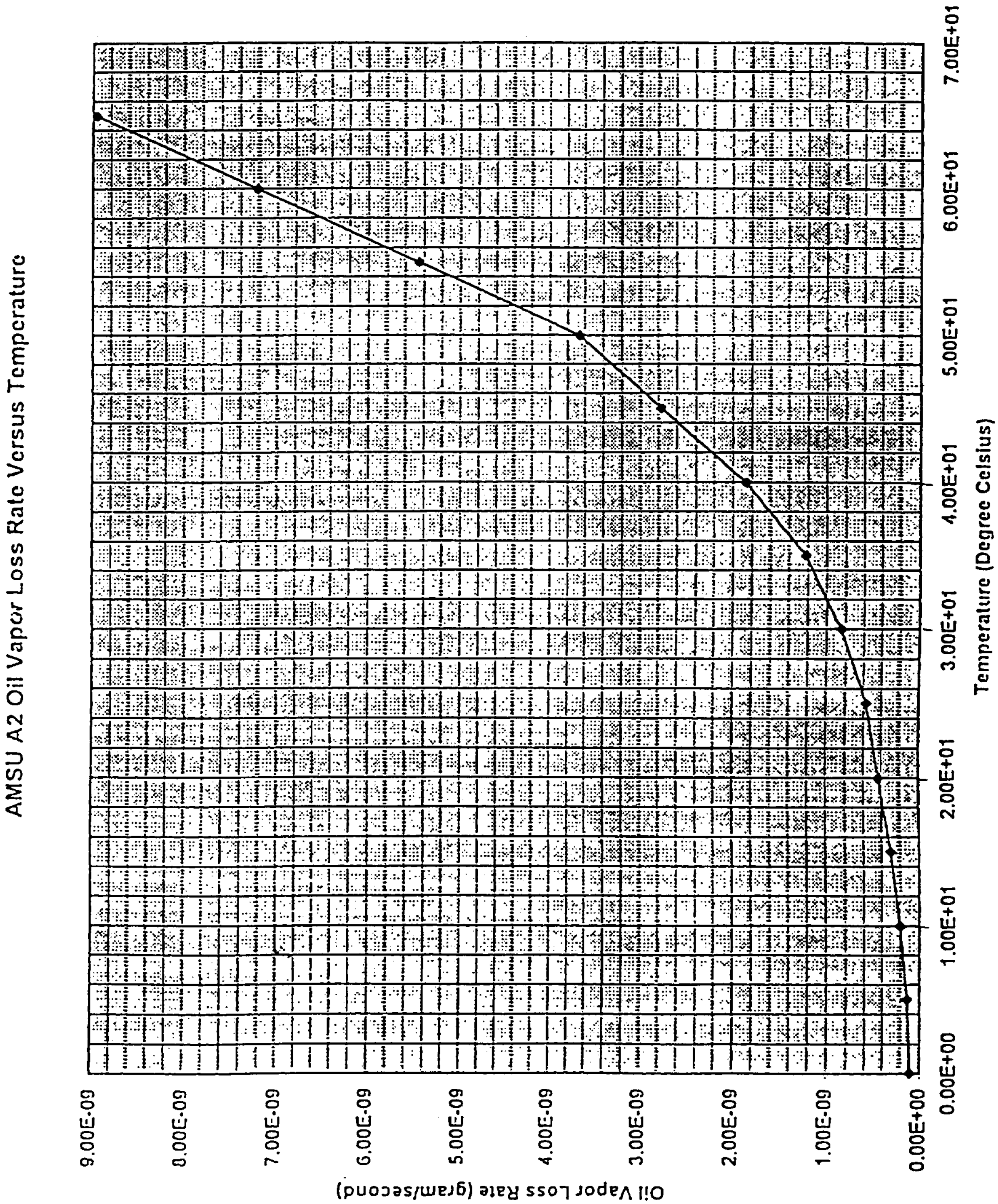

AMSU A2 Oil Vapor Loss Rate Versus Temperature
Oil Vapor Loss Rate (gram/second)
9.00E-09
8.00E-09
7.00E-09
6.00E-09
5.00E-09
4.00E-09
3.00E-09
2.00E-09
1.00E-09
0.00E+00
0.00E+00
1.00E+01
2.00E+01
3.00E+01
4.00E+01
5.00E+01
6.00E+01
7.00E+01
Temperature (Degree Celsius)

FIGURE 6

NASA
National Aeronautics and Space Administration

Report Documentation Page

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7. Author(s) M. Fay		8. Performing Organization Report No. 10353D
		10. Work Unit No. ---
9. Performing Organization Name and Address Aerojet 1100 W. Hollyvale Azusa, CA 91702		11. Contract or Grant No. NAS 5-32314
12. Sponsoring Agency Name and Address NASA Goddard Space Flight Center Greenbelt, Maryland 20771		13. Type of Report and Period Covered Final
		14. Sponsoring Agency Code ---

15. Supplementary Notes

---

16. ABSTRACT (*Maximum 200 words*)

This is the Contamination Control Report, for the Integrated Advanced Microwave Sounding Unit-A (AMSU-A).

17. Key Words (Suggested by Author(s))	18. Distribution Statement
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Unclassified	Unclassified		---

NASA FORM 1626 OCT 86

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4. TITLE AND SUBTITLE Integrated Advanced Microwave Sounding Unit-A (AMSU-A), Contamination Control Report	5. FUNDING NUMBERS NAS 5-32314
6. AUTHOR(S) M. Fay	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Aerojet 1100 W. Hollyvale Azusa, CA 91702	8. PERFORMING ORGANIZATION REPORT NUMBER 10353D 29 October 1998
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11. SUPPLEMENTARY NOTES ---	
12a. DISTRIBUTION/AVAILABILITY STATEMENT ---	12b. DISTRIBUTION CODE ---

13. ABSTRACT (*Maximum 200 words*)

This is the Contamination Control Report, for the Integrated Advanced Microwave Sounding Unit-A (AMSU-A).

14. SUBJECT TERMS EOS Microwave System	15. NUMBER OF PAGES
	16. PRICE CODE ---

17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT SAR

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