P546624
26 October 2001
Rev. A-Draft

FAME

Instrument Requirements Document

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RECORD OF CHANGES

REVISION LETTER	DATE	DESCRIPTION OF CHANGE	ENTERED BY
Draft	07 Dec 2000	Pre-SRR Draft	Lanham
Draft	15 May 2001	Pre-release draft	Horner
Draft	22 May 2001	Pre-release draft	Horner
0	26 June 2001	Initial Release	Horner
A-Draft	26 October 2001	Draft release of Revision A	Horner

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1 INTRODUCTION

1.1 Scope

This document applies to the Full-sky Astrometric Mapping Explorer (FAME) Observatory program, a NASA Medium Class (MIDEX) Explorer mission.

1.2 Instrument Overview

FAME will provide the positions, proper motions, parallaxes, and photometry of nearly all stars as faint as 15th visual magnitude with accuracies of 0.24 nanoradians (50 microarcseconds [μas]) at 9th visual magnitude and 2.4 nanoradians (500 μas) at 15th visual magnitude. Stars will be observed with color filters to measure their photometric magnitudes. The data are acquired by a scanning survey instrument evolved from the *Hipparcos* mission design with a mission life of 5 years.

1.2.1 Science Objectives

Primary science requirements are fully described in the document *FAME Science Requirements (NCST-D-FM001).* The baseline and minimum science requirements are summarized below.

1.2.1.1 Baseline Requirements

The following constitute the baseline mission success criteria for FAME. FAME will create a catalog of star positions based on a 5 year mission with:

1. Measured positions, parallaxes, and proper motions of 40 million stars, accurate to 50 microarcseconds, 50 microarcseconds, and 70 microarcseconds per year, respectively, between 5th and 9th visual magnitude. At 15th visual magnitude the mission astrometric accuracy shall be no worse than 500 microarcseconds.
2. Photometric magnitudes for all stars in the wide band astrometric bandpass as well as the Sloan r' and i' filters. The accuracy of individual observation magnitudes shall range from better than 5 millimagnitudes at 9th magnitude to better than 100 millimagnitudes at 15th magnitude. The mission photometric accuracy shall range from better than 1 millimagnitude at 9th magnitude to better than ten millimagnitudes at 15th magnitude.

The above accuracy specifications apply to the median values for the unconfused sources at a given magnitude.

1.2.1.2 Minimum Requirements

The following constitute the minimum mission success criteria for FAME:

1. Measured positions, parallaxes, and proper motion of 10 million stars accurate to 200 microarcseconds, 200 microarcseconds, and 200 microarcseconds per year respectively at 9th visual magnitude. At 15th visual magnitude the mission astrometric accuracy shall be no worse than 1000 microarcseconds.
2. Photometric magnitudes for all stars in the wide band astrometric bandpass as well as the Sloan r'and i' filters. The accuracy of individual observed magnitudes shall range from better than 10 millimagnitude to better than 200 millimagnitude at 15th magnitude. The mission photometric accuracy shall range from better than 5 millimagnitude at 9th magnitude to better than 20 millimagnitude at 15th magnitude.

The above specifications apply to the median values for the unconfused sources at a given magnitude.

1.2.2 Observatory Description

The FAME Observatory consists of a spacecraft bus and a single instrument subsystem. The Spacecraft Bus will be designed and fabricated at the Naval Research Laboratory. The Instrument will be designed and fabricated at the Lockheed Martin Space Systems Advanced Technology Center. The U.S. Naval Observatory will provide overall project supervision as well as Mission Operations and Data Analysis for the lifetime of the mission.

1.3 Purpose

This document, along with the *FAME Spacecraft Bus to Instrument Interface Control Document (NCST-ICD-FM001),* defines the requirements of the FAME Instrument to be provided by Lockheed Martin under contract N00173-00-C-2039.

Ideally, each of the requirements in this document flow from the scientific through the mission requirements. However, some of these requirements are derived from what is technically feasible and cost-effective, and may or may not have implications for the science and mission requirements. All requirement statements in this document contain the word “shall.” Sentences that do not contain the word “shall” are not considered requirements. Each requirement has a unique paragraph number; there is only one requirement for each lowest level section number. This is done to make the verification matrix as simple as possible. Each and every requirement in this document will be verified. An explaination of the possible verification methods (i.e. test, analysis, etc.) is included with a verification matrix, indicating how each of the requirements in this document will be verified, in the Instrument Verification Plan *(P546617)*. If a requirement is not verified to the level specified in these requirements, a waiver must be issued for the instrument to be released.

1.4 Document Overview

The requirements in this document flow down from the *FAME Mission Requirements Document (NCST-D-FM002)* however, the Instrument will be designed and verified based on the requirements in this document and the *FAME Spacecraft Bus to Instrument Interface Control Document (NCST-ICD-FM001). FAME Document Tree (5873000)* shows the FAME instrument document tree.

This document is organized in accordance with the guidelines contained in *MIL-SPEC-490A*. Some sections may be titled “Reserved” in order to conform to the section numbering guidelines. All requirement statements contain the word “**shall**” in the requirement, and are all contained within Sections 3 and 4.

This document is organized as follows:

Section 1, *Introduction*: The purpose and contents of this document.

Section 2, *Referenced Documents*: A list of documents referenced by this document.

Section 3, *Requirements*: The set of performance, functional, interface and environmental requirements for the FAME Instrument. This section is organized according to the guidance provided in *MIL-STD-490A*. Section 3.1 provides a description of the Instrument and does not contain any requirements. Section 3.2 contains the performance requirements and characteristics of the Instrument. Sections 3.3 – 3.6 contain general requirements that apply to all levels of the Instrument including subsystem and assembly. Section 3.7 contains the specific requirements that pertain only to each subsystem.

Section 4, *Quality Assurance Provisions*: This section provides the requirements and definitions for verifying compliance to the requirements of Section 3. It includes a Verification Cross Reference Matrix relating each requirement in Section 3 to a Verification Method and where appropriate a specific paragraph in Section 4 describing that verification method.

Section 5, *Preparation for Delivery*: This section provides guidance for packaging and shipping the Instrument to the Spacecraft integration site.

Section 6, *Notes*: Includes a list of definitions of terms, a list of acronyms and abbreviations used in this document and until final release at CDR a list of open requirements (those with “TBD” or “TBR”), and the planned closure of each.

Several terms are used throughout this document to identify the absence of requirements in a given paragraph or section. For this specification the words “Reserved” and “Deleted” have special meaning. “Reserved” means that, as of this draft or release, no section title or requirements has been associated with this section number. In future editions this may be replaced by a title and the section may contain requirements. “Deleted” means there were, in a previous draft or release, requirements associated with this section which have been deleted or moved to another section. These sections will not contain requirements in any future release in order to prevent confusion resulting from the reuse of paragraph numbers.

At the beginning of certain paragraphs, explanatory text or definitions may be provided which apply to that section. Such statement will be followed by the designation “[NR]” indicating that the preceding paragraph contains no verifiable requirements.

1.5 Requirements Traceability

To facilitate the tracing of requirement flow and to document the method used to determine requirements, some of the requirements listed in this document will include explanatory text in *italics*. This explanatory text does not contain requirements, only commentary on how the associated requirement was derived.

2 REFERENCED DOCUMENTS

The following documents of the version indicated form a part of this specification to the extent indicated herein. Requirements adopted from referenced documents will be specifically called out within the requirements in this document, and will include the source document paragraph number of the adopted requirement. In the event of conflict between the referenced documents and the contents of this specification, the contents of this specification shall supersede.

2.1 FAME Documents

2.1.1 Specifications

Number	Title	Referenced in Paragraph No.
NCST-D-FM001	FAME Science Requirements	
NCST-D-FM002	FAME Mission Requirements Document	
NCST-D-FM017	FAME Design Loads Analysis Plan	
NCST-ICD-FM001	FAME Spacecraft Bus to Instrument Interface Control Document	
NCST-ICD-FM004	FAME Spacecraft Bus to Instrument Software Interface Control Document	
P546600A	Statement of Work & Development Specification for the FAME CCDs	
P546604	Specification for the FAME Instrument Telescope System	
P546622	Configured Item Specification for the FAME Aperture Door Assembly	
P546626	Specification for the FAME Instrument Structure	
P546630	Window specification	
P546631	Filter specification	

2.1.2 Standards

None.

2.1.3 Other Publications

Number	Title	Referenced in Paragraph No.
P546607	FAME Instrument Systems Engineering Management Plan	
P546610	FAME Instrument Software Management Plan	
P546611	FAME Instrument Operations Concept	
P546612	Performance Assurance Implementation Plan for the FAME Program	
P546613	FAME Instrument EMI/EMC Control Plan	
P546614	FAME Instrument Contamination Control Plan	
NCST-D-FM011	FAME Failure Modes and Effects Analysis	

2.2 Government Documents

2.2.1 Specifications

Number	Title	Referenced in Paragraph No.
MIL-M-38510	Microcircuits, General Specification for	
MSFC-SPEC-522A	Design Criteria for Controlling Stress Corrosion Cracking	
NASM33540	Safety Wiring and Cotter Pinning	

2.2.2 Standards

Number	Title	Referenced in Paragraph No.
MIL-STD-883E	Test Methods and Procedures for Microelectronics	
MIL-STD-961D	Specification Practices	
MIL-STD-975M(2)	NASA Standard Electrical, Electronic, and Electromechanical (EEE) Parts List	
MIL-STD-1543B	Reliability Program Requirements for Space and Launch Vehicles	
MIL-STD-1686C	Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment	
NASA-STD-8739.1	Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies	
NASA-STD-8739.2	Workmanship Standard for Surface Mount Technology	
NASA-STD-8739.3	Soldered Electrical Connections	
NASA-STD-8739.4	Crimping, Interconnecting Cables, Harnesses, and Wiring	
NASA-STD-2100-91	NASA Software Documentation Standard	

2.2.3 Other Publications

Number	Title	Referenced in Paragraph No.
MIL-HDBK-217F	Reliability Prediction of Electronic Equipment	
MIL-HDBK-1547A	Electronic Parts, Materials, & Processes for Space & Launch Vehicles	
EWRR 127-1	Eastern and Western Range Regulation 127-1, Range Safety Requirements	
GSFC 311-INST-001 Revision A	Instructions for EEE Parts Selection, Screening, and Qualification	
GSFC-410-MIDEX-001	MIDEX Assurance Guidelines	
GSFC-410-MIDEX-002	MIDEX Assurance Requirements	
SP-R-0022	Vacuum Stability Requirements of Polymeric Material for Spacecraft Applications, Specifications for	
SSD-D-IM007	ICM Worst Case Analysis	

2.3 Non-Government Documents

2.3.1 Specifications

None.

2.3.2 Standards

Number	Title	Referenced in Paragraph No.
ANSI/J-STD-001	Requirements for Soldered Electrical and Electronic Assemblies	
ANSI/J-STD-002	Solderability Test for Component Leads, Terminations, Lugs, Terminals and Wires	
ANSI/J-STD-003	Solderability Test Methods for Printed Wiring Boards	
ANSI/J-STD-004	Requirements for Soldering Fluxes	
ANSI/J-STD-005	Requirements for Soldering Pastes	
ANSI/J-STD-006	Requirements for Electronic Grade Solder Alloys and Fluxed and Non-fluxed Solid Solder for Electronic Soldering Applications	
IPC-A-600D	Acceptability of Printed Wiring Boards	
IPC-D-275	Standard for PCB Design and Assembly	
IPC-FC-250	Performance Specification for Single and Double-Sided Flexible Printed Boards	
IPC-FC-250A-86	Specifications for Singe and Double-Sided Wiring	

2.3.3 Other Publications

Number	Title	Referenced in Paragraph No.
EG3.1.6-G1	Product Development Verification Guidebook	
	Space Mission Analysis and Design, 3rd Edition, Wertz & Larson, Microcosm Press and Kluwer Academic Publishers, El Segundo, CA, 1999	

3 REQUIREMENTS

3.1 Instrument Definition

3.1.1 Description of the Fame Instrument

The FAME Observatory consists of a spacecraft bus and a single integrated Instrument. This Instrument is comprised of a single telescope imaging two fields of view onto a single focal plane assembly. The two telescope fields of view are separated by a "basic angle" defined in these requirements. The focal plane is populated with a mosaic of CCDs operating in Time Delay Integration (TDI) mode synchronized with the rotation of the Observatory.

3.1.2 Instrument Operations

Observatory operations are described in the *FAME Instrument Operations Concept (P546611)*. Observatory operations officially begin with the delivery of the Observatory to Pre-Launch operations. This document includes two earlier phases, Instrument Integration & Test and Observatory Integration & Test to provide a complete picture of the operational requirements levied on the Instrument. A table of possible Instrument power states during the Observatory mission phases is provided in Section (TBD) of the *FAME Spacecraft Bus to Instrument Interface Control Document (NCST-ICD-FM001)*.

3.1.2.1 Instrument Integration and Test Phase

This phase begins with the integration of the first subsystems of the Instrument and ends with the arrival of the Instrument at the Spacecraft test facility. The Instrument will undergo interface, performance, and environmental verification as described in Section 4 to assure that the requirements of this document are met and to measure the extent to which the goals have been met.

During this phase, special alignment devices and test interfaces may be employed to fabricate, integrate, align and verify that the Instrument meets requirements. The sequence of integration, test and verification activities will be established in the *FAME Instrument Integration Plan (P546615)* and the *FAME Instrument Test Plan (P546616).* This phase includes packaging and transportation of the Instrument to the Spacecraft test facility.

3.1.2.2 Observatory Integration and Test Phase

This phase begins with the arrival of the Instrument at the Spacecraft test facility. The phase ends with the arrival of the Observatory (Spacecraft Bus and Instrument) and associated GSE at the launch site. The Observatory will undergo interface verification to assure compatibility with the ground segment. During this phase special alignment devices and test interfaces will be employed to fabricate, integrate, align and verify that the Instrument meets requirements. The sequence of integration, test and verification activities will be established in the *FAME System Integration and Test Plan (NCST-TP-FM001).* This phase includes packaging and transportation of the FAME Observatory to the launch site.

3.1.2.3 Pre-Launch Phase

This phase begins with the arrival of the Observatory (Spacecraft Bus and Instrument) and associated GSE at the launch site and ends with lift-off from the launch site. The Observatory will be integrated with the final boost motor to form the Flight Vehicle. The flight vehicle will then be mated with the Launch Vehicle and final preparations for launch will be completed. The Instrument basic functionality tests, as described in the *FAME Instrument Test Plan (P546616)*, will be performed after the Observatory has arrived at KSC.

One important activity in this phase is to verify that all "remove before flight" tagged items are removed from the Instrument. This includes any covers, connector savers and removable items that were required for Pre-Launch operations.

3.1.2.4 Launch Phase

During launch, the S/C controller, receivers, Sun sensors and power control electronics will not have power. The Instrument is in Off State and the aperture doors will remain closed. The star trackers and antenna mounted on the Instrument structure will be active but will not require the Instrument to provide any power or data links.

Launch phase concludes when the Observatory separates from the booster third stage at the Marman clamp. The launch vehicle has despun the third stage and Observatory to a rotation rate close to zero prior to separation.

3.1.2.5 Geosynchronous Transfer Orbit (GTO) Phase

Launch phase ends and GTO phase begins when the Marman clamp releases the Observatory from the third stage of the launch vehicle. The Observatory is in a 10.6 hour orbit with an apogee of GEO+300 km. The Sun shield remains stowed during this phase, and the Observatory is spinning at the moderate rotation rate of 1 rpm (TBR) about the **+z** axis with the Sun in the **x-y** plate to provide power to the bus via the stowed Sun shield arrays. The Observatory is in contact with ground control via Blossom point and DSN. The Instrument is in FPA Decontamination State and the aperture doors remain closed. GTO phase ends after the third orbit when the Observatory is spun up to 60 rpm and the AKM is fired.

3.1.2.6 SuperSync Phase

SuperSync Phase begins after the AKM is fired. The AKM burn brings the Observatory to a circular orbit at the supersynchronous or GEO disposal orbit at GEO+300 km. During this phase, the Observatory drifts west to the western stable point. The Observatory is in 24 hour contact with Blossom Point from this point forward. Once the Observatory reaches 105° west longitude, the orbit is elipiticized so that perigee is at GEO and apogee is at GEO + 300 km. The Instrument is in FPA Decontamination State and the aperture doors remain closed. SuperSync Phase ends with a hydrazine thruster firing to lower perigee.

3.1.2.7 Early GEO Operations Phase

Early GEO Operations Phase begins when the hydrazine thrusters are fired to lower the perigee to the operations orbit, slightly elliptical (eccentricity = 0.0071) with apogee at GEO+300 km and perigee at GEO-300 km. The Instrument is in FPA Decontamination State, Survival State, or Operating State and the aperture doors will remain closed. Early GEO Operations concludes with the opening of the Instrument aperture doors by the Spacecraft Bus.

3.1.2.8 Engineering and Calibration Phase

Engineering and Calibration Phase begins with the opening of the aperture doors and concludes with the commencement of scientific operations. The Instrument is in either Operating State or Survival State and the aperture doors are open.

3.1.2.9 Science Phase

Science Phase begins with the first transition into Acquisition Mode. Science Phase is complete when the mission lifetime has elapsed. The Instrument is in either Operating State or Survival State and the aperture doors are open.

3.1.2.10 Disposal Phase

Disposal Phase begins at the end of the Mission Lifetime. Instrument power is switched off as well as survival heater power. A single hydrazine thruster burn elevates perigee to GEO+300 km to circularize the orbit at GEO+300 km. The Instrument is in the Off State.

3.1.2.11 Instrument States and Modes in Relation to Observatory Operations

The *FAME Instrument Operations Concept (P546611)* contains a mission timeline and a description of the Instrument states and modes within each of the mission phases. Table 3-1 shows the possible Instrument states during all of the mission phases.

Table 3-1: Instrument States during Mission Phases

Mission Phase	Observatory State	Nominal Instrument Power States					
		Off	FPA Decontamination	Survival	Boot	Standby	Operating
Ground Test		X	X	X	X	X	X
S/C Integration		X	X	X	X	X	X
Launch		X					
GTO			X	X			
Supersync			X	X			
Early GEO			X	X			
Engineering and Calibration				X	X	X	X
	Operating				X	X	X
	Station Keeping			X	X	X	
	Safe			X			
Science				X	X	X	X
	Operating				X	X	X
	Station Keeping			X	X	X	
	Safe			X			
Disposal		X					

3.2 Instrument Requirements

3.2.1 Instrument Performance

3.2.1.1 Separated Fields of View

The FAME Instrument **shall** consist of a single telescope fed by two fields of view separated by a basic angle in the plane perpendicular to the Observatory symmetry axis.

The FAME Instrument uses observations of two fields of view onto a single focal plane to determine astrometric positions over large separations in the sky as well as to determine absolute parallaxes rather than relative parallaxes.

3.2.1.2 Field of View

Each telescope aperture **shall** have a field of view $\geq 1.0°$ in diameter.

The FAME unvignetted FoV needs to be wide to obtain a large number of observations of each of the catalog stars. The size of the field of view determines the rate of precession due to the need for subsequent great circles to overlap. This ultimately determines the number of observations obtained in a fixed period of time.

3.2.1.3 Aperture

The FAME Instrument apertures **shall** be a 40 cm $\times$ 9 cm or larger rectangle.

The point spread function for the rectangular apertures is described in FAME-EM017. Discussion of aperture shapes is presented in the FAME Phase B Kick-off Meeting presentations.

3.2.1.4 Telescope Focal Length

The focal length of the FAME telescope **shall** be 9.5 < F < 13.0 meters.

The optimal focal length for FAME is determined by the standard sizes of the CCD pixels, the size of the FAME telescope PSFs, the size of the focal plane, and the FoV of the telescope. The upper bound is defined by the focal plane physical size, which is determined by the number of CCDs in requirement 3.2.1.14 and the size of the CCDs, combined with the FoV defined in requirement 3.2.1.2. The lower bound is set by the size of the aperture in the scan direction as defined in requirement 3.2.1.3, and the requirement for a minimum of 2.5 pixels between the first minimums of the PSF in the scan direction.

3.2.1.5 Spectral Response

The Instrument spectral response for the astrometric CCDs (total Instrument throughput/efficiency including the CCD quantum efficiency but without photometric filters) **shall** as defined in Table 3-2.

Table 3-2: Instrument throughput/efficiency

Wavelength (nm)	Efficiency
400	≤ 1%
500	≤ 1%
600	≥ 45%
700	≥ 40%
800	≥ 25%
900	≤ 1%
1000	≤ 1%

The values in Table 3-2 were determined by the analysis in FAME-EM017. The FAME Instrument will have an operational waveband of 550 - 850 nm and will be designed to observe average stars (F0V) in the magnitude range of $5 \leq m_v \leq 15$

3.2.1.6 Photometry

The FAME Instrument **shall** make photometric observations in two bandpasses.

The colors of the FAME catalog stars will need to be determined by FAME to determine the appropriate PSF to use in the astrometric data reductions.

3.2.1.7 Overall Optical Quality

The FAME optical system **shall** have a total wavefront error of ≤ 0.075 λ RMS at λ = 650 nm.

The ability of the opticians to manufacture the FAME optics combined with the integration alignment errors and the on-orbit alignment shifts due to launch loads, temperature changes, and dehydration of the composite structure set the overall optical quality. The λ/13.4 requirement above provides diffraction limited performance.

3.2.1.8 Distortion

The Instrument deviations from a linear mapping due to optical distortion, using the f-θ definition, **shall** be ≤ ±5 µm over the FAME field of view

The distortion (classical aberration due to a changing effective focal length across the field of view) needs to be limited in the scan direction to reduce smearing of the star PSFs as they cross the CCDs (see FAME-EM005).

3.2.1.9 Lateral Color

The Instrument optical systems lateral color, as defined by the centroids of the spot diagrams, **shall** have ≤ ±3 μm of relative offset as a function of wavelength over the FAME bandpass and field of view.

Shifts of the PSFs as a function of wavelength will shift the star PSFs different amounts for different color stars.

3.2.1.10 Stray Light and Ghosting

3.2.1.10.1 Earth

The Instrument **shall** have a ≤ 0.7 steradian area around the Earth where the stray light at the focal plane from Earthshine is $\geq 3.2 \times 10^{-9}$ ergs/s/pixel.

3.2.1.10.2 Point Source

TBD.

3.2.1.10.3 Ghosting

TBD.

3.2.1.11 Basic Angle Stability

The basic angle of the FAME Instrument **shall** vary by no more than +/-50 picorad (10 μas) over a 10 minute period.

The basic angle is defined as the angle between the two fields of view, thus this requirement encompasses the entire FAME optical system of which the compound mirror is only one part. This requirement flows from the ultimate mission accuracy of 50 μas. The value of the basic angle needs to be known to high accuracy to establish the FAME reference frame. Either the basic angle needs to be stable over time so that it can be determined as an independent parameter from the observations themselves, or an independent measure of the basic angle (i.e. using analysis and the measured compound mirror temperature profile) needs to be provided.

3.2.1.12 Focus stability

The Instrument focus **shall** not require refocusing/alignment more than once a month on average. The threshold for refocusing will be a λ/40 RMS change in the wavefront.

A λ/40 RMS wavefront error is equivalent to a despace between the primary and secondary of 2 µm or more. Refocusing should not have to occur more than once per month.

3.2.1.13 Focal Plane Alignment to Instrument Interface

The columns of the CCDs need to be aligned with the rotation axis of the Observatory so that the star images cross as few columns as possible.

3.2.1.13.1 CCD alignment to the FPA

All CCDs **shall** be aligned relative to a fiducial on the focal plane assembly to better than ±0.5 milliradians (2/4096; 2 columns out of 4096 rows).

This coaligns the CCDs to a single line on the FPA.

3.2.1.13.2 FPA alignment to the Instrument alignment cube

The alignment of the Instrument alignment cube to the FPA fiducial, as projected through the FAME optical telescope assembly, **shall** be known to ≤10 μradians (2 arcsec) (TBR).

This aligns the image of the line to which the CCDs will be aligned on the FPA to the corner cube that NRL will use to determine the proper alignment of the Instrument to the Spacecraft Bus.

3.2.1.13.3 FPA alignment to the Instrument mounting interface

The alignment of the Instrument interface plane to the FPA fiducial, as projected through the FAME optical telescope assembly, **shall** be ≤0.0018 radians (0.1 degrees).

The FPA fiducial as projected though the optical system needs to remain within the bounds of adjustment of the Instrument/Spacecraft Bus mechanical interface adjustability.

3.2.1.14 Detectors

The focal plane of the FAME telescope **shall** contain 13 independent CCDs arranged within the unvignetted FoV to maximize the astrometric resolution and accuracy. There will be 2 CCDs with photometric filters.

There are 11 CCDs for astrometry and 2 CCDs have photometric filters.

3.2.1.15 Electronic noise

The electronic read noise of the detector system **shall** be ≤ 13.3 e- for binned by 24 windows.

This is the RMS of the CCD read noise and the electronics read noise. The electronics noise impacts the power required by the filter boards in the FPA and thus impact the CCD temperature/radiator size.

3.2.1.16 Timing Accuracy

3.2.1.16.1 Frequency

The Instrument **shall** use a 50 MHz oscillator.

3.2.1.16.2 Stability

The Instrument **shall** use an oscillator stable to $\leq 2.0\times10^{-10}$ over 1000 s.

3.2.1.16.3 SC-Cut Crystal

The Instrument **shall** use an oscillator with a stress compensated cut crystal.

3.2.1.17 Instrument States and modes

The Instrument **shall** support the states and modes described in Table 3-3.

Table 3-3: Instrument States and Modes

Instrument State	Operating Mode	Instrument Electronics Boxes	Instrument Heaters	FPA Deconta-mination Heaters	Survival Heaters	Description
Off		**Off**	**Off**	**Off**	**Off**	Instrument is completely unpowered
FPA Decontamination		**Off**	**Off**	**On**	**On**	FPA decontamination heaters are on to prevent the CCDs and FPA window from behaving like a cold trap
Survival		**Off**	**Off**	**Off**	**On**	Instrument temperature is maintained but the Instrument is off (**Safe mode**)
Standby		**On**	**On**	**Off**	**Off**	Instrument is on but is not clocking the CCDs
Operating	Engineering					Instrument is on and is clocking the CCDs, the instrument memory is configured in engineering mode
	Acquisition					Instrument is on and is clocking the CCDs, the instrument memory is configured in acquisition mode
	Science					Instrument is on and is clocking the CCDs, the instrument memory is configured in science mode

3.2.1.18 Input Catalog

Requirement deleted.

3.2.1.19 Maximum star rate

Requirement deleted.

3.2.1.20 Attitude Determination

Requirement deleted.

3.2.1.20.1 Attitude accuracy

Requirement deleted.

3.2.1.20.2 Rotation rate accuracy

Requirement deleted.

3.2.1.21 Location of PSF Peak

Requirement deleted.

3.2.1.22 Data Windows

3.2.1.22.1 Engineering Mode

3.2.1.22.1.1 Window sizes

In Engineering Mode, the Instrument **shall** support engineering mode windows in sizes up to 900 × 1024 pixels.

3.2.1.22.1.2 Binning

In Engineering Mode, the Instrument **shall** collect unbinned pixel data.

Engineering mode windows will always be unbinned.

3.2.1.22.1.3 Number of windows

In Engineering Mode, the Instrument **shall** support at least 1 window per CCD half and at least 1 window over the entire focal plane.

3.2.1.22.2 Acquisition Mode

3.2.1.22.2.1 Window sizes

In Acquisition Mode, the Instrument **shall** support acquisition mode windows in sizes up to 600 × 600 pixels.

These windows are used for spacecraft trim and acquisition modes.

3.2.1.22.2.2 Binning

In Acquisition Mode, the Instrument **shall** collect pixel data binned by 2 columns in the row direction.

Acquisition mode windows will always be binned by 2.

3.2.1.22.2.3 Number of windows

In Acquisition Mode, the Instrument **shall** support at least 2 windows per CCD half with a combined number of windows on the focal plane of at least 2.

3.2.1.22.3 Science Mode

3.2.1.22.3.1 Window sizes

In Science Mode, the Instrument **shall** support science mode windows in 2 window sizes, with the size set by stored parameters, up to 30 × 64 pixels with an even number of columns.

Smaller windows can be used for single stars and large windows can be used for double stars.

3.2.1.22.3.2 Binning

In Science Mode, the Instrument **shall** collect pixel data binned by any even number of columns in the row direction on the CCD up to the width of the window in columns.

3.2.1.22.3.3 Number of windows

*In Science Mode, the Instrument **shall** support at least 500 windows per CCD half.*

3.2.1.23 Science Mode Window Binning
Requirement deleted (incorporated into 3.2.1.22).

3.2.1.24 Flat fields
The Instrument **shall** provide illumination sources within the Instrument structure for flat field characterization of the Instrument.

3.2.1.25 Charge Injection
The CCDs **shall** incorporate a split charge injection serial register and input transfer gate to support charge injection on a pixel by pixel basis.

3.2.2 Physical Characteristics

3.2.2.1 Spacecraft Interfaces
The interface between the Spacecraft and the Instrument includes mechanical, electrical, thermal, optical (glint FOV) and RF interface requirements. Some mechanical interface requirements such as loads, FOV, jitter and mass properties are provided in Sections TBD, TBD, and TBD, respectively, of this document. Some electrical interface requirements such as EMI and power are also provided in the appropriate sections of this document. All remaining quantitative Spacecraft Bus to Instrument requirements are provided as statements, not requirements. The defining requirements are provided in the *FAME Spacecraft Bus to Instrument Interface Control Document (NCST-ICD-FM001)*.

3.2.2.1.1 S/C Antenna
The Instrument **shall** be designed to support an antenna and the associated wiring harness to be supplied and integrated by NRL as specified in *FAME Spacecraft Bus to Instrument Interface Control Document (NCST-ICD-FM001)*.

3.2.2.1.2 S/C Star Tracker Support
The Instrument **shall** be designed to support two star trackers and the associated wiring harnesses to be supplied and integrated by NRL as specified in *FAME Spacecraft Bus to Instrument Interface Control Document (NCST-ICD-FM001)*.

3.2.2.2 Units
The units presented in all Instrument documents and drawings will be expressed in SI units with other applicable units included in parentheses where applicable. Both English and Metric units will be specified on all Instrument to Spacecraft Bus Interface documents and drawings.

3.2.2.3 Mass Properties
The FAME Instrument total mass and mass properties requirements are specified in the *FAME Spacecraft Bus to Instrument Interface Control Document (NCST-ICD-FM001)*. This allocation is for the Instrument provided by LM to NRL and excludes the mass of the star trackers, omni antenna, star tracker/antenna mounting bracket, and star tracker/antenna wiring harness(es) supplied by NRL to be mounted on the Instrument structure.

3.2.2.4 First Vibration Mode

3.2.2.4.1 Instrument Assembly
The Instrument assembly **shall** have a first vibration mode > 50 Hz.

3.2.2.4.2 Secondary Components
Each Instrument secondary component **shall** have a first vibration mode > 75 Hz.

3.2.2.5 Coordinate Systems

3.2.2.5.1 Observatory coordinate system
The FAME Observatory coordinate system is defined as shown in Figure 3-1. The Observatory coordinate system origin is located on the Spacecraft to Instrument mating plane, the surface that is formed by the bottom of the Instrument flexure feet. The $\mathbf{x_O}$=0, $\mathbf{y_O}$=0 point is the center point of the circle formed by the six mounting holes in the interface feet.

The coordinate system is a right-handed rectilinear system with the $\mathbf{x_O}$-$\mathbf{y_O}$ plane parallel to the Launch Vehicle Separation plane (and Spacecraft Bus-Instrument interface plane). The $\mathbf{z_O}$-axis is through the center of the satellite attach interface in the direction of the Observatory rotation vector and is positive in the anti-Sun direction. The $\mathbf{y_O}$-axis parallel to the primary-secondary optical axis of the FAME telescope and is positive in the fold mirror direction (secondary and compound mirror are at negative $\mathbf{y_O}$, and the primary is at a positive $\mathbf{y_O}$). The $\mathbf{x_O}$-axis is oriented relative to these in a right-handed coordinate system.

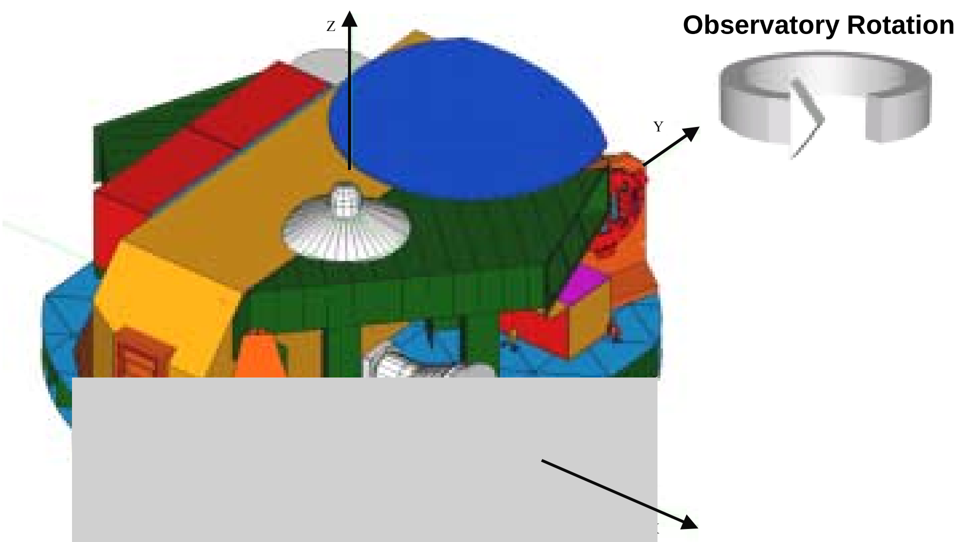

Figure 3-1: Observatory coordinate system and rotation direction

The direction of the FAME rotation must be defined to orient the scan direction of the CCDs on the FPA with the rotation of the Observatory. The FAME Observatory will rotate in a right-handed sense (from $\mathbf{x_O}$ to $\mathbf{y_O}$) or counterclockwise when observed from $\mathbf{z_O} = +\infty$.

The *upper* telescope aperture faces the positive-$\mathbf{x_O}$, positive-$\mathbf{y_O}$ quadrant of the coordinate system, and the *lower* telescope aperture faces the negative-$\mathbf{x_O}$, positive-$\mathbf{y_O}$ quadrant.

3.2.2.5.2 Focal Plane Assembly Coordinate System
The origin of the FPA coordinate system is at the geometric center of the FPA baseplate, with **w**=0 at the surface of the FPA baseplate on the CCD side (facing +**w**). The **u**-axis is the fiducial on the FPA in the direction of the star motion as the Observatory rotates (the star image positions increase in **u** over time).

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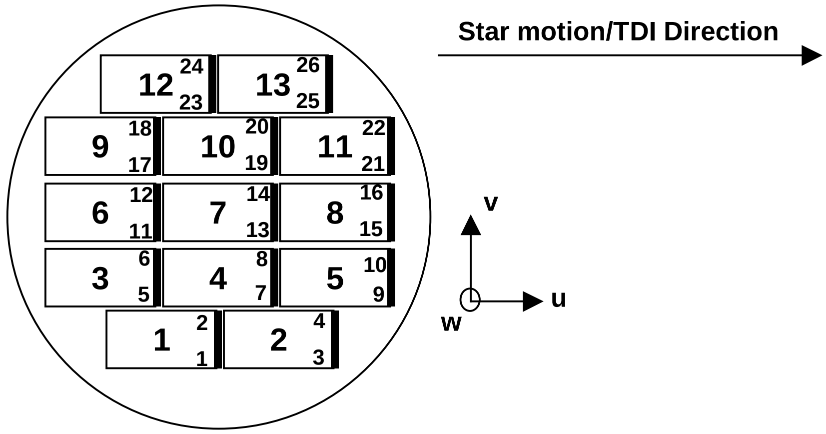


Figure 3-2: Focal plane assembly coordinate system and nomenclature. The black bar represents the output serial register (34 pin connector end) of the CCD.

The FPA is physically mounted in the FAME Instrument rotated relative to the Observatory coordinate system due to the angle of the fold mirror. The FPA is mounted with **+w** in the **–x$_O$ +y$_O$** direction, **+u** in the **-x$_O$ -y$_O$** direction, and **+v** in the **+z$_O$** direction, as shown in Figure 3-3.

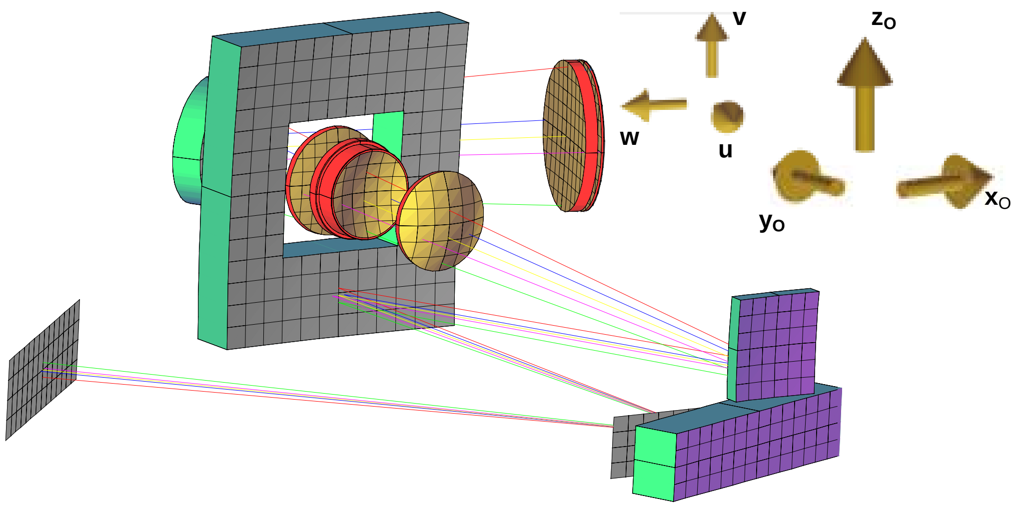


Figure 3-3: Orientation of FPA coordinates relative to Observatory coordinates

Through the optical system, the **+z$_O$** axis is projected in the **-v** direction on the focal plane. The Observatory rotates counterclockwise when seen from **+z$_O$**, which results in the apparent motion of stars on focal plane in the **+u** direction.

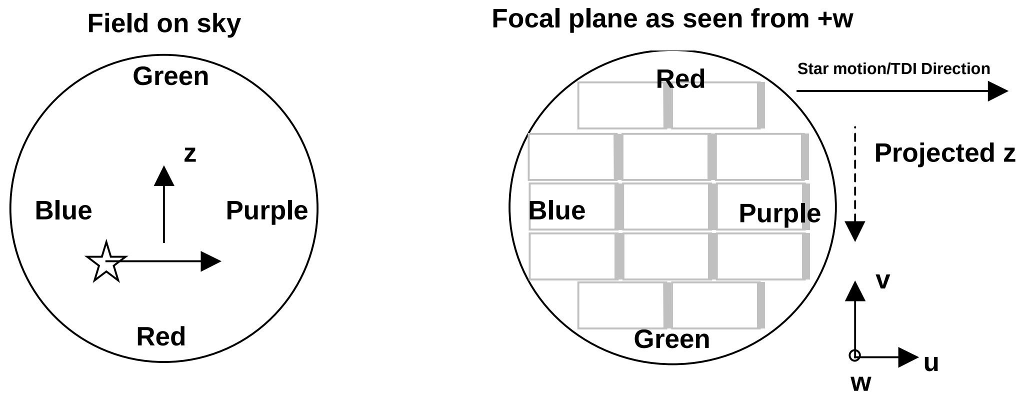


Figure 3-4: Projection of the sky onto the FPA. The written colors correspond to the colors used in the raytrace in Figure 3-3. On the left is a view of a field on the sky and the right is how that field is projected onto the FPA by the FAME optics as seen from through the FPA window (from +w).

3.2.2.5.3 CCD Nomenclature

Individual pixels on the CCD are indexed using (r, c) where r represents the row number and c represents the column number. Thus the pixel in the lower left corner of the CCD in Figure 3-5, is pixel (0,0), and the pixel in the lower right is pixel (4095,0).

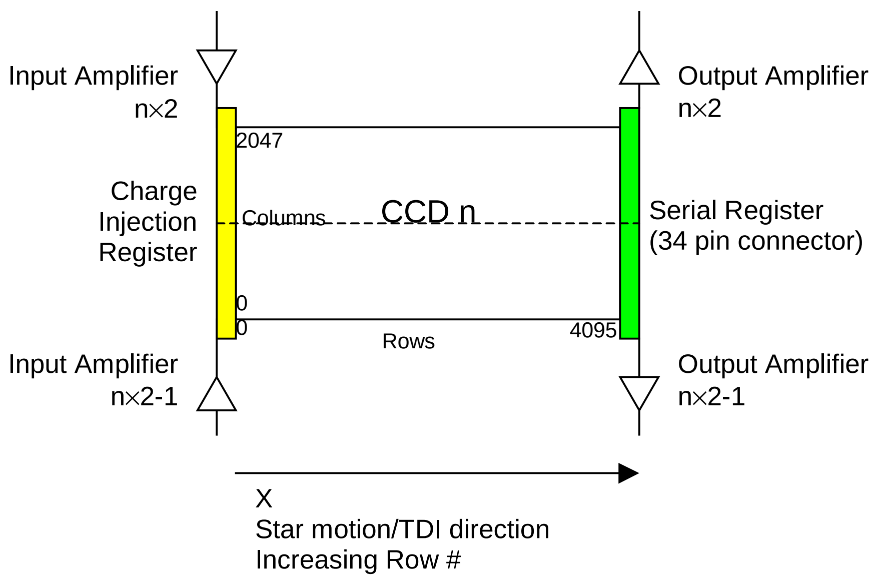


Figure 3-5: CCD nomenclature.

3.2.3 Mechanical Factors of Safety

3.2.3.1 Flight Unit
The factors of safety used for protoflight testing of the flight Instrument hardware **shall** be as defined in Table 3-4.

Table 3-4: Factors of Safety

Factor of Safety	No Test	With Test:
Yield	1.4	1.10
Ultimate	2.0	1.40
Composite Ultimate	N/A	1.50
Local Buckling	N/A	1.25
Overall Stability	N/A	1.40
Bonded Joint Adhesive, Ultimate	N/A	1.50
ULE, Zerodur	N/A	1.0*
Mechanical Test		1.05
*1500psi design allowable as documented by Goodrich		

3.2.3.2 Composite Material
The composite material uncertainty factor **shall** be 1.33.

3.2.3.3 Ground Systems Equipment (GSE)
GSE **shall** be analyzed and tested to the standards of LMSSC Occupational Safety and Health Standards, Section 6.3.

3.2.4 Environmental Characteristics

3.2.4.1 Mission Lifetime
The Instrument **shall** perform as specified for 5 years (requirement) after exposure to the environments specified herein for launch and ascent (Section 3.2.4.3) and on-orbit operations (Section 3.2.4.4).

3.2.4.2 Ground Handling and Transportation
The Instrument **shall** meet the requirements of this document without refurbishment or adjustment after exposure to any combination of the ground handling and transportation environments listed below:

3.2.4.2.1 Ambient Air Temperature
The Instrument **shall** survive an uncontrolled external ambient air temperature that can range from -10°C to +40°C.

3.2.4.2.2 Ambient Pressure
The Instrument **shall** survive an ambient pressure naturally occurring at sea level to 30,000 feet.

3.2.4.2.3 Humidity
The Instrument **shall** be packaged to survive humidity levels between 30% and 90%. Appropriate measures will be implemented to prevent the formation of condensation on the Instrument, test equipment, or protective covers.

3.2.4.2.4 Acceleration, Vibration, Shock, and Loads
The Instrument **shall** not be exposed to environments greater than those experienced during launch and ascent.

3.2.4.2.5 Cleanliness

Protective container or packaging to maintain flight hardware at the cleanliness level specified in *FAME Instrument Contamination Control Plan (P546614).*

3.2.4.3 Launch

3.2.4.3.1 Loads

For the purposes of this section the term "primary structure" refers to the FAME Instrument frame structure, the FPA monocoque, and all its components. The term 'secondary structures" refers to electronics boxes and other assemblies attached to the primary structure. [NR]

Except for the early on-orbit accelerations, the Instrument will be in a non-operational state during exposure to these environments. During early on-orbit operations the Instrument will not be expected to meet performance requirements, but it will be expected to meet all performance levels after exposure. [NR]

3.2.4.3.1.1 Primary Structure

The FAME Instrument primary structure **shall** be designed to withstand the static accelerations Listed in Table 3-5.

Table 3-5: Primary Structure Launch and On-Orbit Limit Accelerations

	Instrument Accelerations		
LOAD CASE	**Axial, g**	**Lateral, g**	**Rotational, rad/s^2**
LV Liftoff	3.9 (TBR) -0.3 (TBR)	+7.0 (TBR) -7.0 (TBR)	47.2 (TBR) -47.2 (TBR)
LV MECO	+10.2 (TBR) -0.5 (TBR)	+0.4 (TBR) -0.4 (TBR)	1.6 (TBR) -1.6 (TBR)
SC AKM Firing	+6.1 (TBR) 0 (TBR)	60 RPM	
On Orbit	TBD	TBD	

3.2.4.3.1.2 Secondary Structure

The FAME Instrument secondary structures **shall** be designed to withstand the static accelerations listed in Figure 3-6.

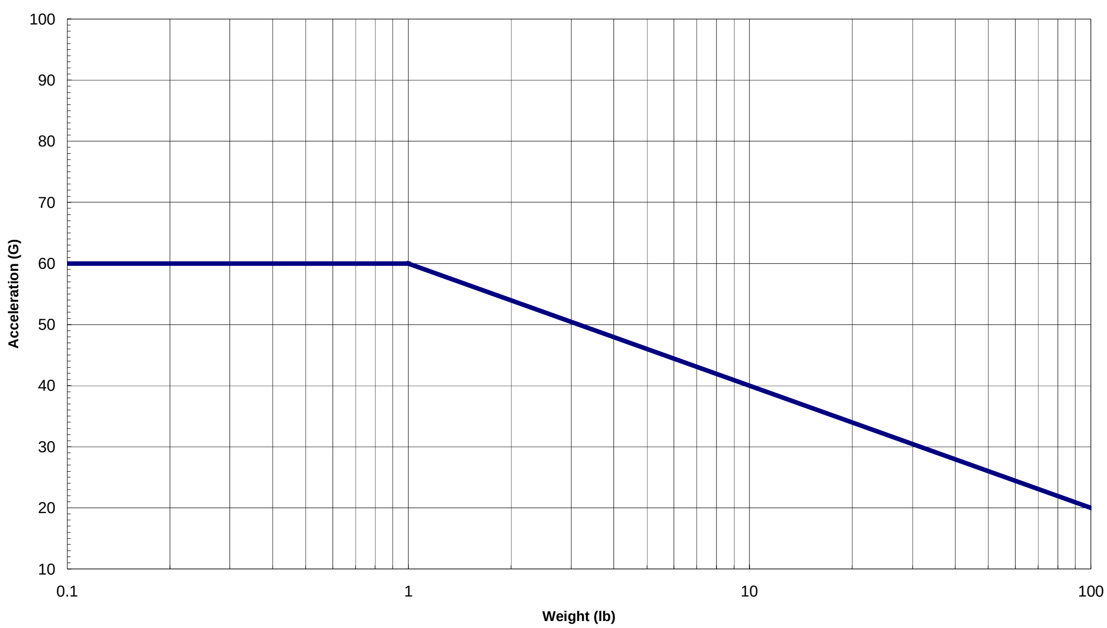
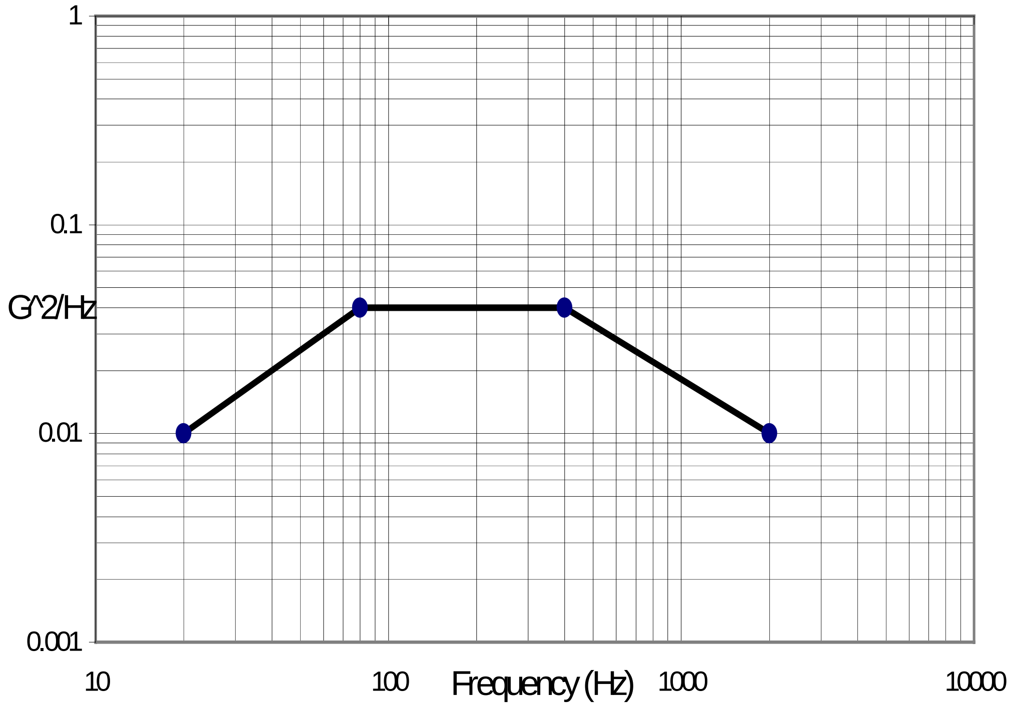


Figure 3-6: Secondary Structure Launch and On-Orbit Limit Accelerations

3.2.4.3.2 Vibration

3.2.4.3.2.1 Component Level

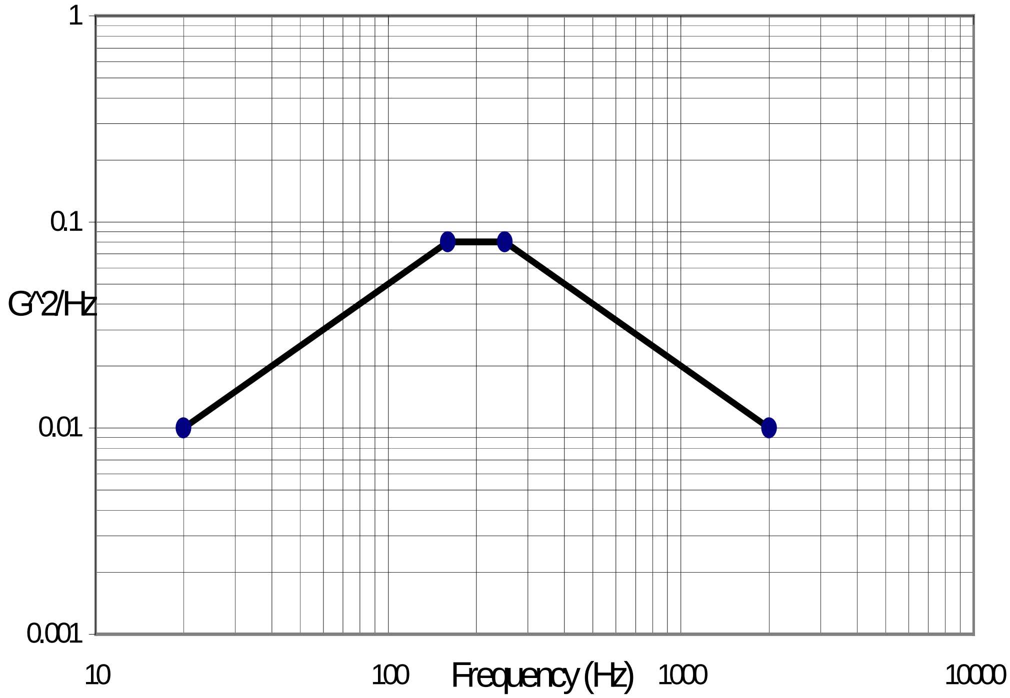
The FAME Instrument components **shall** withstand the axial and cross axis, launch vibration levels show in Figures 3-7 through 3-10 and in the included tables.



Flight Level Environment	
20	0.01
80	0.04
400	0.04
2000	0.01
6.6 G_{rms}	

Test Level	Margin Above Flight Level (dB)	Duration (Minutes)
Non-Flight Prototypes (Design & Qual Level)	6	2
Flight Units (Protoflight Accept Test)	3	2

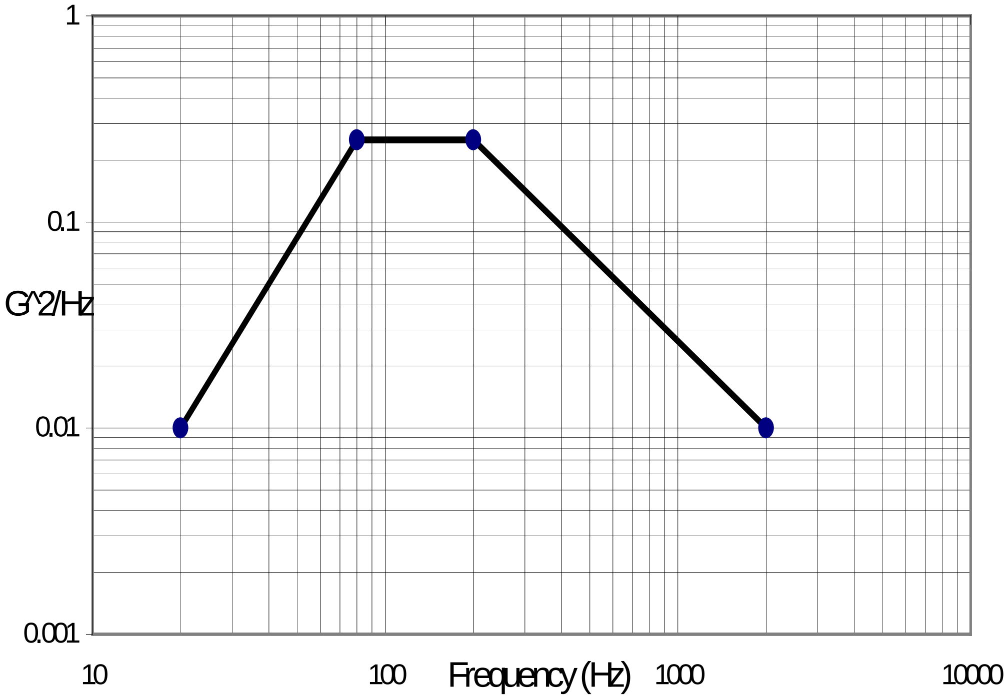
Figure 3-7: Random Vibration Environment, Compound Mirror, All 3 Axes



Flight Level Environment	
20	0.01
160	0.08
250	0.08
2000	0.01
7.4 Grms	

Test Level	Margin Above Flight Level (dB)	Duration (Minutes)
Non-Flight Prototypes (Design & Qual Level)	6	2
Flight Units (Protoflight Accept Test)	3	2

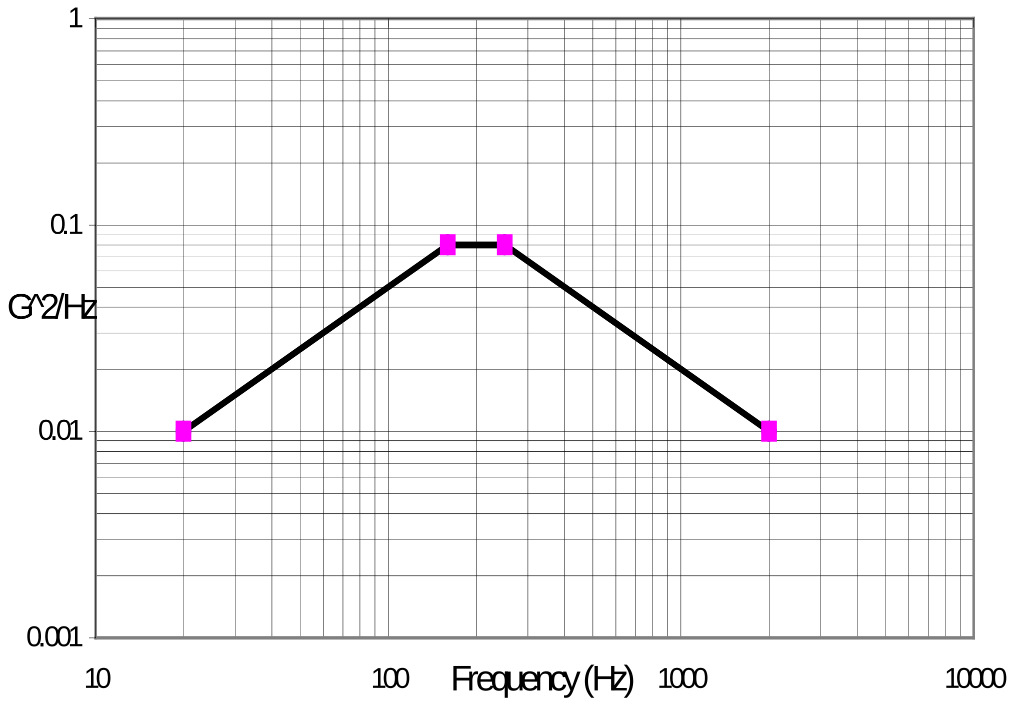
Figure 3-8: Random Vibration Environment, Frame Mounted Compounds/Mirrors, All 3 Axes



Flight Level Environment	
20	0.01
80	0.25
200	0.25
2000	0.01
10.6 Grms	

	Test Level	
	Margin Above Flight Level (dB)	Duration (Minutes)
Non-Flight Prototypes (Design & Qual Level)	6	2
Flight Units (Protoflight Accept Test)	3	2

Figure 3-9: Random Vibration Environment, Panel Mounted Components/CCDs, Axes Normal to Mounting Plane



Flight Level Environment	
20	0.01
160	0.08
250	0.08
2000	0.01
7.4 Grms	

Test Level	Margin Above Flight Level (dB)	Duration (Minutes)
Non-Flight Prototypes (Design & Qual Level)	6	2
Flight Units (Protoflight Accept Test)	3	2

Figure 3-10: Random Vibration Environment, Panel Mounted Components/CCDs, Axes Lateral to Mounting Plane

3.2.4.3.2.2 Instrument Level

The flight level random vibration environment for the system is given in Figure 3-11. The protoflight test level for the flight unit is +3dB higher than the flight level for a duration of 2 minutes and the qualification test level for the engineering model is +6 dB higher than flight for a duration of 2 minutes.

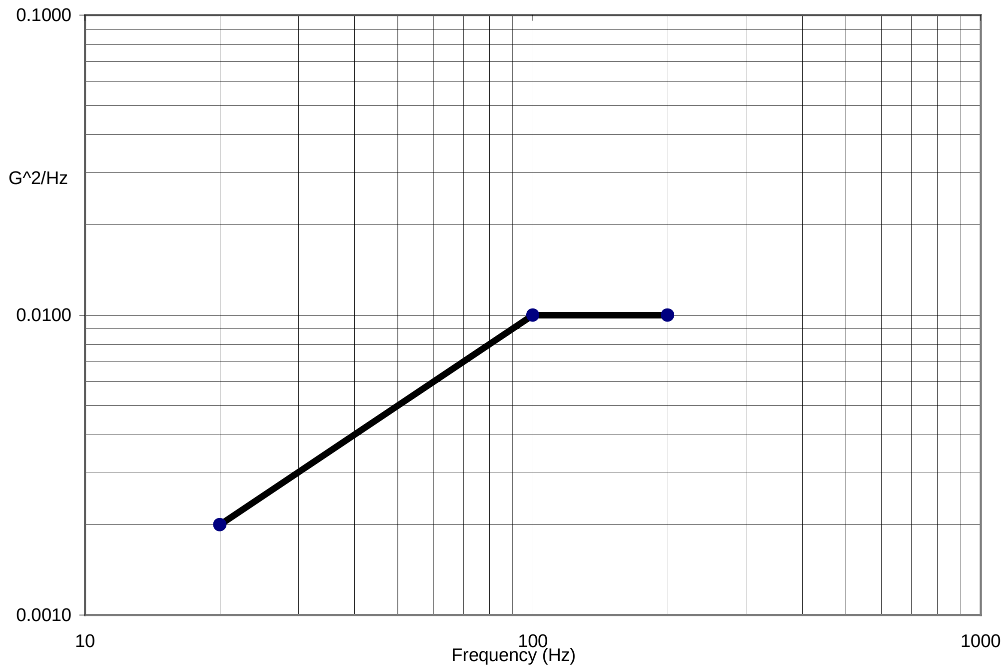
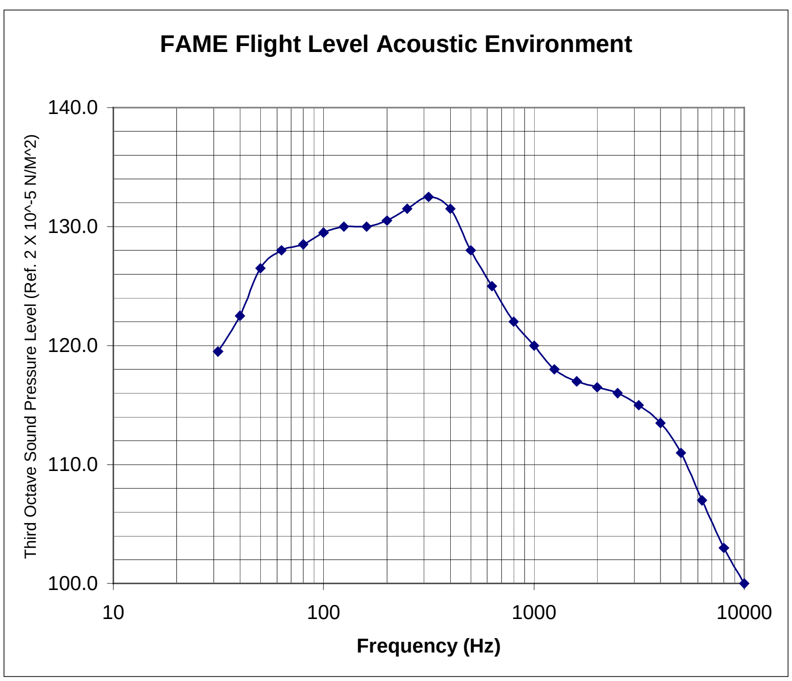


Figure 3-11: Instrument Vibration Level

3.2.4.3.3 Acoustic

The FAME Instrument and its components **shall** survive the Acoustic Environment shown in Figure 3-12.



One Third Octave Frequency (Hz)	SPL (dB)
32	119.5
40	122.5
50	126.5
63	128.0
80	128.5
100	129.5
125	130.0
160	130.0
200	130.5
250	131.5
315	132.5
400	131.5
500	128.0
630	125.0
800	122.0
1000	120.0
1250	118.0
1600	117.0
2000	116.5
2500	116.0
3150	115.0
4000	113.5
5000	111.0
6300	107.0
8000	103.0
10000	100.0
OA	140.8
Duration	1 Minute

Figure 3-12: FAME Instrument Acoustic Environment

3.2.4.3.4 Shock

The Instrument **shall** be capable of operating after being exposed to the shock levels provided in Table 3-6 and Figure 3-13.

Table 3-6: Instrument Component Shock Levels.

Design Environment Shock Response Spectrum Levels		Test Levels	
Frequency (Hz)	G's	Flight	1 Shock per Axis
100	50	Protoflight	2 Shocks per Axis
800	375		
10000	375	Qualification	3 Shocks per Axis
Q = 10			

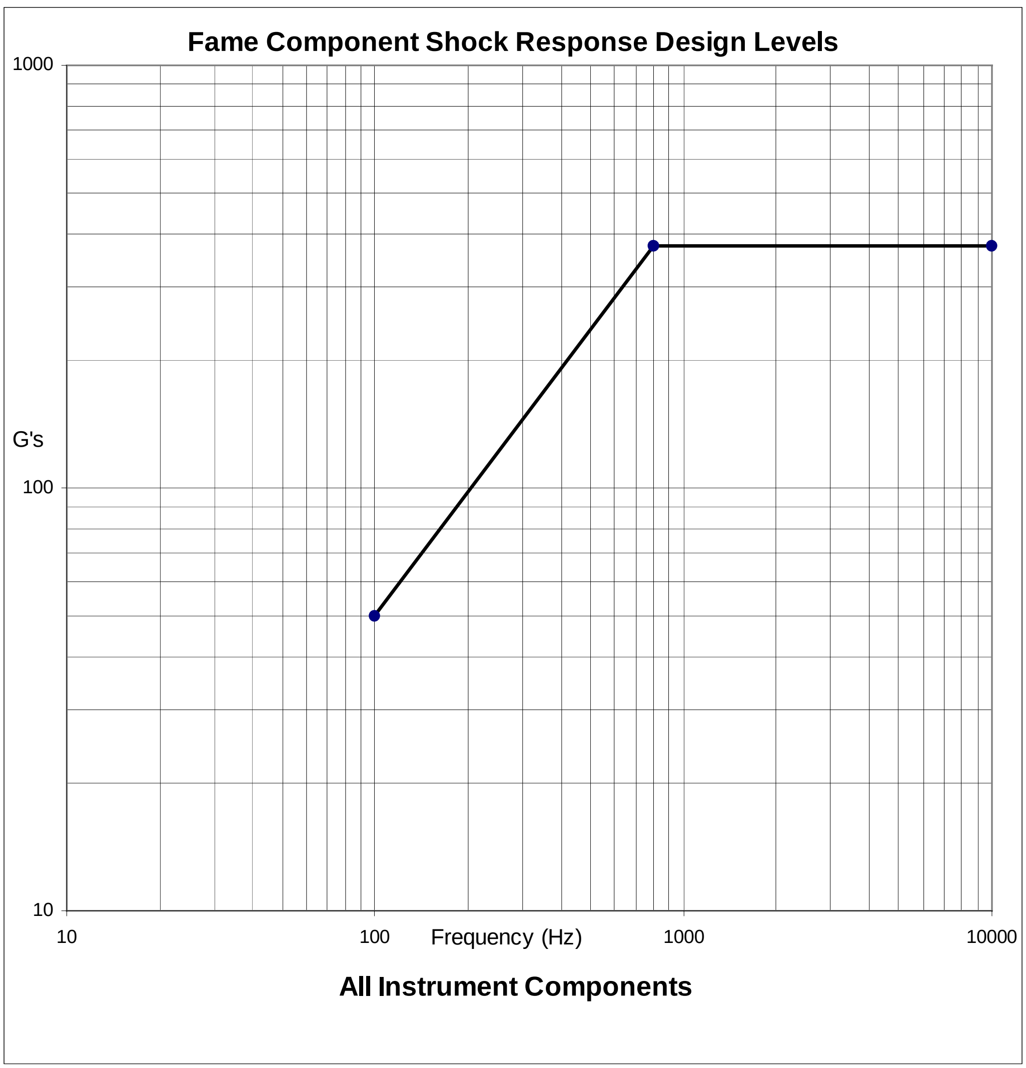


Figure 3-13: Instrument Component Shock Levels (Q=10), All Three Axes

3.2.4.3.5 Thermal

The thermal environment for the FAME S/C is given in Figure 3-14. This data represents the thermal environment for a Delta II 2925-10 Launch Vehicle.

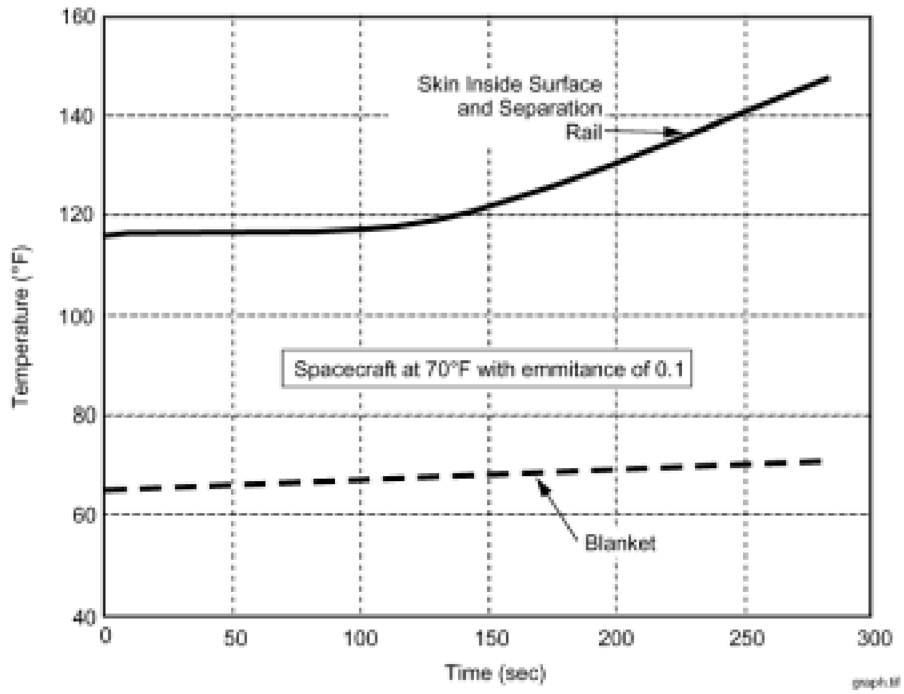


Figure 3-14: Predicted maximum internal wall temperature and internal surface emittance (10-ft fairing)

3.2.4.3.6 Pressure/Depressurization

The pressure environment for the FAME S/C is given in Figure 3-15. This data represents the pressure environment for a Delta II 2925-10 Launch Vehicle.

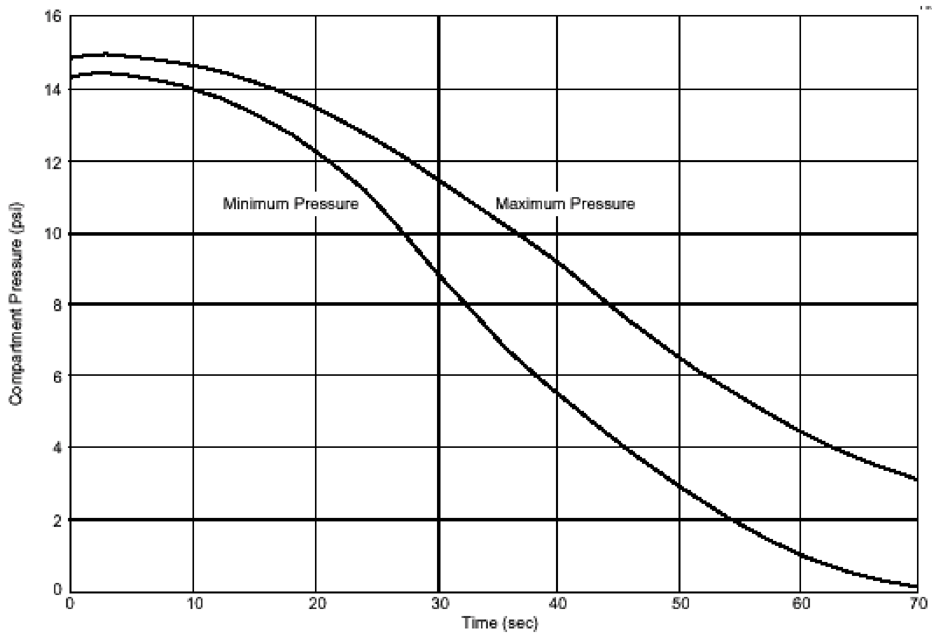


Figure 3-15: Pressure profile and depressurization rates for Delta II 10-ft diameter fairing

3.2.4.4 On-orbit

The FAME operational orbit will be slightly elliptical (e=0.0119) at GEO±300 km with an inclination <30.4°. The mission orbit will have a LAN at 105.5°, RAN of 191° ± 10°, and AOP of 149°.

3.2.4.4.1 Shock

The Instrument **shall** be capable of operating after being exposed to the shock levels defined in Section 3.2.4.3.4.

3.2.4.4.2 Thermal

The Instrument **shall** be capable of operating in the thermal environment defined in Table 3-7.

Table 3-7: On-orbit Thermal Environment

Heat Load	Cold Case	Hot Case
Solar Flux	1308 W/m^2	1400 W/m^2
Earthshine	232 W/m^2	276 W/m^2
Albedo	0.21	0.3

3.2.4.4.3 Pressure

The observatory shall meet the requirements of this document while operating in a hard vacuum of less than 1 x 10^{-5} torr.

3.2.4.4.4 Cosmic Ray and High Energy Proton Environment

3.2.4.4.4.1 Particle Radiation

The observatory will be subjected to galactic cosmic radiation, geomagnetically trapped particle radiation, and solar particle event (SPE) radiation (Table 3-9). It is imperative that mission critical electronics continue to operate within specifications until the end of the 5 year extended mission and during the worst case solar activity. Therefore, design requirements **shall** address Total Ionizing Dose (TID) and Single Event Effects (SEE) as required by paragraph 5.8 of GSFC-410-MIDEX-001. The anticipated 5 year observatory radiation environment is shown in Figure 3-16.

Table 3-8: FAME Radiation Dose Estimates and Requirements for 5-Year Mission Duration Beginning in November 2004

Hemisphere Aluminum Shielding Thickness	Total Dose +0% Margin for 5 Year Mission
mils(Al)	**rads(Si)**
0.5	4.68E+08
5.0	1.15E+08
10.0	5.25E+07
25.0	1.14E+07
50.0	2.47E+06
75.0	8.37E+05
100.0	3.36E+05
125.0	1.46E+05
150.0	6.66E+04
175.0	3.27E+04
200.0	1.82E+04
225.0	1.14E+04
250.0	7.79E+03
275.0	5.65E+03
300.0	4.35E+03
350.0	3.06E+03
400.0	2.56E+03

Note 1. The 2-π hemispherical shielding assumes that substantial satellite structures attenuate the radiation environment in the other hemisphere (e.g. boxes near a surface). 4-π geometry may be a more appropriate where structures are deep within the satellite.

Note 2. Spherical shielding is usually a conservative assumption, and refined dose estimates based on ray tracing sector analyses will lead to lower doses for box geometries of equal thickness.

Note 3. Solar protons are not expected after solar minimum starts in March of 2006, so the 2.5 and 5 year proton doses are the same.

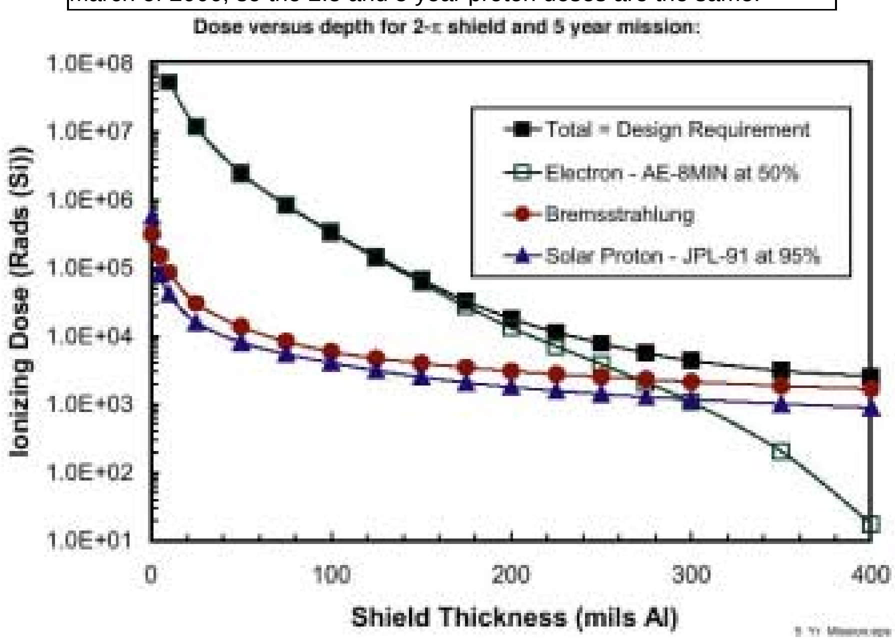


Figure 3-16: Observatory Radiation Environment – Dose versus depth for 2π and 5 year mission

3.2.4.4.4.2 Total Ionizing Dose

3.2.4.4.4.2.1 Total Ionizing Dose

Any part used in the observatory **shall** meet the requirements of this document at a minimum TID failure level of 18.2 krad(Si). This level is arrived at using the depth-dose relation of Table 3-9 with an assumed hemispherical shield thickness of 200 mils Al. The minimum hardness level of 18.2 krad(Si) also includes a factor of 2 that is recommended for uncertainty in the environment.

3.2.4.4.4.2.2 Documentation

Any part that does not meet this minimum requirement of 18.2 krad(Si) **shall** be identified in the Preliminary Design Review (PDR) and Critical Design Review (CDR), and its suitability for use demonstrated with an appropriate shielding analysis that includes both trapped particle and solar particle contributions.

3.2.4.4.4.3 Single Event Effects

SEE **shall** be considered for the galactic cosmic ray environment and for the worst expected SPE.

3.2.4.4.4.3.1 Galactic Cosmic Rays

The galactic cosmic ray design environment for the nominal case of 150 mils Al shielding during solar minimum conditions is shown in Figure 3-17.

3.2.4.4.4.3.2 Solar Proton Events

The observatory will be subjected to occasional SPE producing high fluxes (>10^5 p/cm^2/s) for short periods and with elevated levels for periods of up to several days. While the science mission may be interrupted during SPE, the events must not compromise the survival of the observatory or the completion of the science mission objectives.

3.2.4.4.4.3.3 Worst case spectrum

For SEE analyses, the design worst-case particle flux spectrum (corresponding to the October 89 SPE) is provided in Figure 3-18. Calculation of error rates due to protons may be performed using proton test data and standard tools such as the Bendel formalism found in the CRÈME96 model.

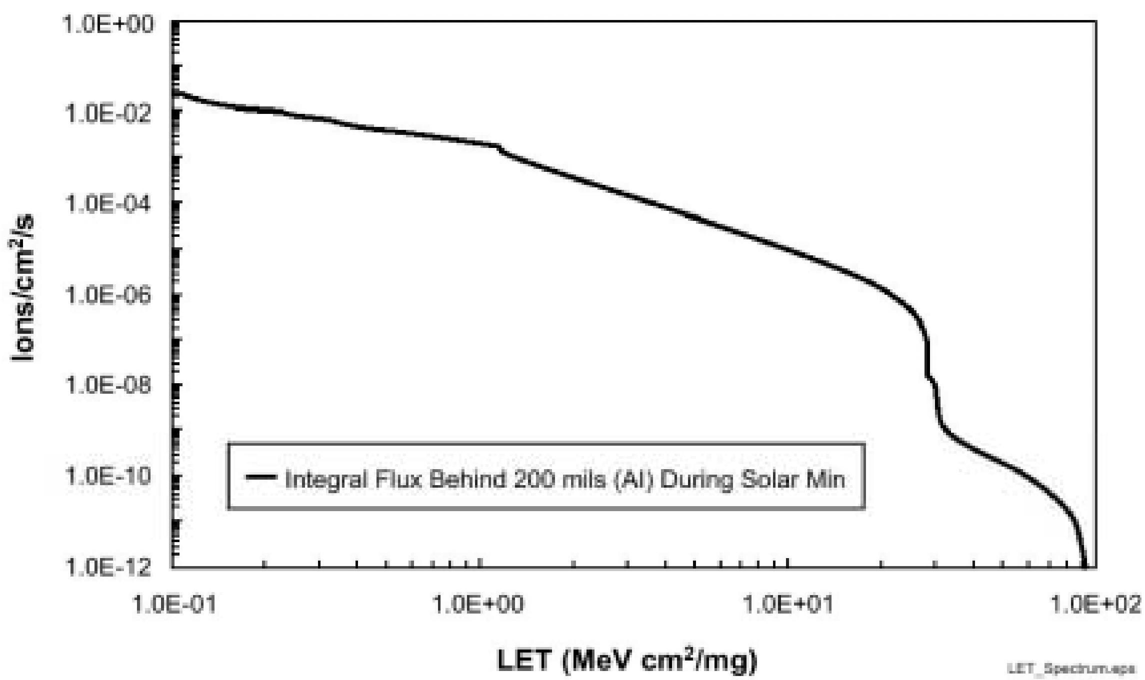


Figure 3-17: FAME Cosmic Ray LET Spectrum - Calculated during solar minimum (normal) conditions with 200 mils Al hemispherical shielding and 0 GV geomagnetic cutoff.

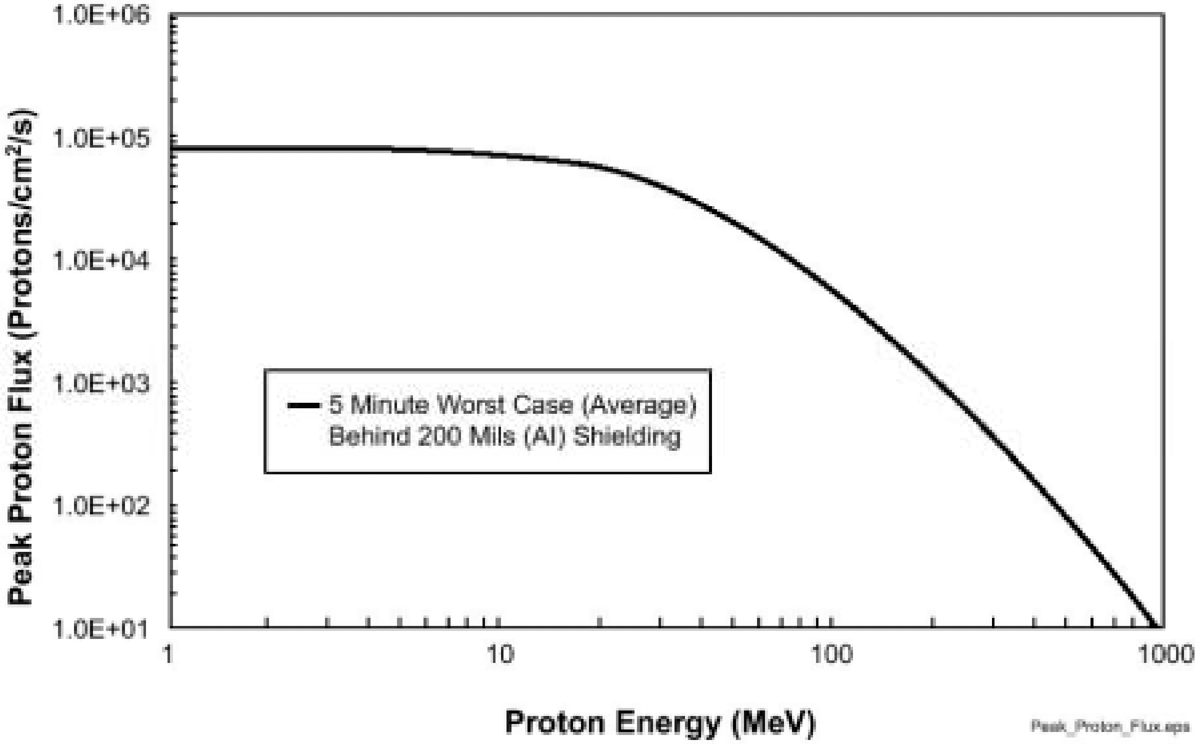


Figure 3-18: Integral Solar Particle Peak Proton Flux

3.2.4.4.4.4 Single Event Induced Destructive Failure

3.2.4.4.4.4.1 Destructive Failure

Mission critical components **shall** not be susceptible to single event induced failure (including latchup, burnout, gate rupture, and secondary breakdown) unless the SEL effects can be mitigated by design.

3.2.4.4.4.4.2 Documentation

Where single event failure cannot be ruled out the part **shall** be identified at PDR/CDR and its use, along with mitigation approach, justified.

3.2.4.4.4.5 Single Event Induced Non-Destructive Failure

3.2.4.4.4.5.1 Non-destructive Failure

Nondestructive SEE (including the failure modes of non-destructive latchup, mini-latchup, and Single Event Functional Interrupts [SEFI]) **shall** not cause mission failure, compromise mission health, or impact mission performance.

3.2.4.4.4.5.2 Documentation

The use of parts with these non-destructive failure modes may be allowed if analyses can show that they do not cause uncorrectable errors or impact system performance. Such parts **shall** be identified at PDR/CDR, along with failure impact and mitigation strategy (e.g., watchdog timer with autonomous power cycle or reset command).

3.2.4.4.4.6 Single Event Induced Soft Errors

3.2.4.4.4.6.1 Soft Errors

Nondestructive SEE (including SEU or transients in linear devices) **shall** not cause mission failure, compromise mission health, or impact mission performance.

3.2.4.4.4.6.2 Documentation

The use of parts with soft error modes may be allowed if analyses show that uncorrectable errors or impacts to system performance do not occur. Such parts **shall** be identified at PDR/CDR, along with failure impact and mitigation strategy (e.g., Error Detection and Correction [EDAC] on memories or filters on linears).

3.2.4.4.5 On-Orbit Glint Environment

TBD

3.2.4.4.6 EMI/EMC

The Instrument **shall** be designed to according to the *FAME Instrument EMI/EMC Control Plan* (P546613).

3.2.4.4.7 Charging

Charging in the Instrument due to the space environment will be controlled in accordance to *the FAME Instrument EMI/EMC Control Plan* (P546613).

3.3 Design and Construction

The following paragraphs describe the general requirements for design and construction that are applicable to the Observatory space segment.

3.3.1 Parts, Materials, and Processes (PMP)

A PMP program **shall** be implemented in accordance with the requirements of the *Performance Assurance Implementation Plan for the FAME Program (P546612)*, that implements the guidelines contained in GSFC-410-MIDEX-001, paragraph 5.1, *Parts*, and paragraph 5.2, *Materials and Processes*.

3.3.1.1 Parts

3.3.1.1.1 Radiation hardness

The radiation hardness characteristics of all EEE parts **shall** be established, implemented, and maintained. Resultant data **shall** be presented for review at the PDR and CDR.

3.3.1.1.2 Nonstandard parts

Nonstandard parts may be used where standard parts do not exist or are not available.

3.3.1.1.3 Cables

Interconnecting cables, harnesses, and wiring **shall** be selected in accordance with the guidelines of NASA-STD-8739.4, *NASA Technical Standard Crimping, Interconnecting Cables, Harnesses, and Wiring*.

3.3.1.1.4 Part removal

Electronic parts and materials that have been permanently installed in an assembly and which are then removed from an assembly for any reason **shall** not be used in any item of spaceflight hardware.

3.3.1.1.5 EEE Standard Parts Selection Criteria

The goal of the EEE parts program is to provide the highest reliability level available within the program and schedule limitations.

3.3.1.1.5.1 Standard EEE Parts

Standard EEE parts **shall** be selected in accordance with GSFC 311-INST-001 Revision A with a quality level no lower than Level 2.

3.3.1.1.5.2 Nonstandard Parts

All other parts selection **shall** be considered nonstandard and **shall** be presented for review at the PDR and CDR.

3.3.1.1.6 EEE Parts Procurement, Processing, and Screening

The following guidelines **shall** be used for establishment of the FAME parts program.

3.3.1.1.6.1 Procurement and Screening

EEE parts **shall** be procured and screened as specified herein, except that rescreening of JANTXV devices is not required, and requirements for a coordinated parts procurement do not apply. A parts control board is optional.

3.3.1.1.6.2 Screening Requirements

Specific FAME program parts screening requirements are as follows:

3.3.1.1.6.2.1 GIDEP

The parts program **shall** provide for a review of Government-Industry Data Exchange Program (GIDEP) alerts, notices, and advisories and provide notification to NRL on affected parts and assemblies.

3.3.1.1.6.2.2 Inspection and PIND

Microcircuits and semiconductors shall be subjected to radiographic (X-ray) inspection and Particle Impact Noise Detection (PIND) as appropriate to their construction.

3.3.1.1.6.2.3 Nonstandard parts

Parts screening guidelines **shall** be required for all nonstandard parts.

3.3.1.1.6.2.4 Microcircuits

Microcircuits per MIL-M-38510 are preferred. However, microcircuits that are fully compliant with paragraph 1.2.1 of MIL-STD-883 may be used with approval from the FAME Project Management Office (PMO). If a microcircuit is not a Qualified Parts List (QPL) class B part or purchased from a Qualified Manufacturer List (QML) vendor, then it **shall** be considered as nonstandard and subject to review at the PDR and CDR.

3.3.1.1.6.2.5 Destructive Physical Analysis

The decision criteria to perform Destructive Physical Analysis (DPA) will be in accordance with the guidelines provided in GSFC 311-INST-001 Revision A for a quality level no lower than Level 2. Except as otherwise specified in paragraph 5.2 of GSFC-410-MIDEX-001, a DPA should not be required unless it is deemed necessary as indicated by failure history, GIDEP alert, or a parts control board.

3.3.1.1.6.2.6 Documentation

The parts program **shall** ensure that the results of receiving inspection, parts tests, material review boards, and parts problems reported from system testing are documented and periodically reviewed.

3.3.1.1.7 EEE Parts Stress Derating

As part of the design process, all EEE parts **shall** be derated such that the applied stresses do not exceed the derating criteria guidelines of MIL-STD-975M.

3.3.1.1.8 Electrostatic Discharge Sensitive EEE Parts

3.3.1.1.8.1 Handling, Shipment, and Storage

All electrical components using ESD parts **shall** provide adequate protection to preclude part failure resulting from handling, shipment, or storage situation.

3.3.1.1.8.2 ESD protection

ESD protection **shall** be in accordance with approved processes and procedures in LAC SPEC 3250 that implements MIL-STD-1686.

3.3.1.2 Materials

3.3.1.2.1 Outgassing

Materials exhibiting total mass loss (TML) of 1.0% or less and collected volatile condensable material (CVCM) values of 0.1% or less **shall** be used in accordance with SP-R-0022.

3.3.1.2.2 Structural and Metallic Materials

MSFC-SPEC-522B Table I materials are strongly preferred. MSFC-SPEC-522B Table II and Table III materials should receive careful consideration and **shall** be identified at the PDF and CDR.

3.3.1.2.2.1 Corrosion Resistance

Metallic materials **shall** be corrosion resistant by nature or **shall** be corrosion inhibited by means of protective coatings.

3.3.1.2.2.2 Galvanic Couples

Base metals intended for intermetallic contact that form galvanic couples **shall** be plated with those metals that reduce the potential difference or **shall** be suitably insulated by a nonconducting finish.

3.3.1.2.2.3 Corrosion Protection

Electrical bonding methods **shall** include provisions for corrosion protection of mating surfaces. Use of dissimilar metals **shall** be avoided.

3.3.1.2.3 Magnetic Materials

The residual dipole of the FAME space segment must be minimized and the use of permanently magnetized materials should be avoided whenever possible. When permanently magnetized materials must be used, they **shall** be identified, along with the field intensity caused by the material, at the PDR and CDR.

3.3.1.2.4 Finishes

3.3.1.2.4.1 Cadmium and Zinc

Cadmium and zinc coatings **shall** not be used.

3.3.1.2.4.2 Tin Coating

Pure tin coated components **shall** not be used within electronic boxes.

3.3.1.2.5 Stress Corrosion

Materials **shall** be selected to control stress corrosion cracking in accordance with MSFC-SPEC-522B, *Design Criteria for Controlling Stress Corrosion Cracking*.

3.3.1.2.6 Polymer Materials.

Uralane **shall** be used for conformal coating applications without UV indicators such as Calciflour. PEMS applications **shall** utilize Paralane for conformal coating material without UV indicators such as Calciflour.

3.3.1.3 Processes

3.3.1.3.1 Soldering and Other Processes.

Soldering and other processes **shall** be specified in approved process specifications.

3.3.1.3.1.1 Special processes

Special processes (e.g. adhesive bonding, plating, etc.) **shall** be in accordance with approved process specifications.

3.3.1.3.1.2 Soldering

Soldering of electrical connections **shall** be in accordance with process specifications that implement NHB 5300.4(3A-2) or NASA-STD-8739.3 and NASA-STD-8739.4 guidelines.

3.3.1.3.1.3 Crimping

Crimping of electrical connections **shall** be in accordance with process specifications that implement NHB 5300.4(3H) or NASA-STD-8739.4 guidelines.

3.3.1.3.1.4 Conformal Coating

Conformal Coating and staking of printed wiring boards and electronic assemblies **shall** be in accordance with process specifications that implement NHB 5300.4(3J) or NASA-STD-8739.1 guidelines.

3.3.1.3.1.5 Printed Circuit Boards

Printed Circuit Boards (PCBs) used in the fabrication of the equipment **shall** conform to the requirements of IPC-D-275, Standard for PCB Design and Assembly; IPC-FC-250, Performance Specification for Single and Double-Sided Flexible Printed Boards, IPC-FC-250A-86, Specification for Single and Double-Sided Flexible Wiring; and IPC-A-600D, Acceptability of Printed Wiring Boards (or their equivalents) or NASA-STD-8739.2.

3.3.1.3.2 Traceability Process

A system for categorizing PMP and EEE parts into sets of homogeneous groups and tracing those parts through the fabrication, assembly, test, and delivery cycles **shall** be maintained.

3.3.1.3.2.1 Scope of traceability

The item's PMP **shall** be traceable from the initial vendor of part, material, or component through the completed hardware item.

3.3.1.3.2.2 Tracked Data

EEE parts **shall** be traced by part number, serial number (when available), and lot number.

3.3.1.3.2.2.1 Fabrication Records

Fabrication records (i.e., travelers) **shall** be maintained that are capable of providing two-way traceability from the first stages of assembly through final acceptance testing.

3.3.1.3.2.2.2 Installation

Specific entries **shall** be made, recording this information as parts are installed.

3.3.1.3.2.2.3 Records

Traceability records **shall** be as shown in Table 3-10.

Table 3-9: Traceability and Lot Control

Part	Relevant Information
Electronic Piece Parts	Mfg/Date/Lot Code
Printed Circuit Boards	Serial Number
Potting/Adhesives/Coatings	Batch Number
Plating of Electronic Housings	Production/Manufacturer Lot Number
Modules and Assemblies	Serial Number
Connectors	Manufacturer Lot Number and Date Code
Chassis Case and Structures	Lot or Heat Treat Number

3.3.1.3.2.3 Piece Parts

All electronics piece parts installed **shall** be identified and documented in order to be traceable to a specific manufacturer, lot number, or data lot code.

3.3.1.3.2.4 Fight Unit Records

A record **shall** be prepared for each flight unit that provides the following information for each EEE part that is installed:

(1) Part number and location;

(2) Manufacturer;

(3) Lot number or date code; and

(4) Serial number (when necessary).

3.3.1.3.3 Failure Reporting and Corrective Action System

The Instrument **shall** implement a closed loop failure reporting system as described in the *Performance Assurance Implementation Plan for the FAME Program (P546612).*

3.3.2 Electromagnetic Environment

The Instrument **shall** be designed and constructed such that each item is compatible with itself, with the ELV, with the launch range, and with its on-orbit operational environments in accordance with the *FAME Instrument EMI/EMC Control Plan (P546613).*

3.3.3 Corona Suppression

The Instrument **shall** be designed to minimize the occurrence of corona discharge in all normal operating environments.

3.3.4 Product Marking

Instrument components that are interchangeable **shall** be identified by part number and serial number or lot number.

3.3.5 Workmanship

3.3.5.1 Process Specifications

All parts and assemblies **shall** be designed and manufactured in accordance with LM-approved process specifications or drawings.

3.3.5.2 Defects

All parts and assemblies **shall** be free of defects that would interfere with operational use, such as excessive scratches, nicks, burrs, loose material, contamination, and corrosion.

3.3.6 Safety

3.3.6.1 General

Design, operation, and testing of the Instrument and its GSE **shall** satisfy the requirements of EWRR 127-1, Chapters 3 and 5.

3.3.6.2 Health Hazards

No health hazards **shall** exist when the Instrument is removed from its container, maintained, installed, or in storage.

3.3.6.3 Storage and Transportation

The Instrument **shall** be capable of being safely stored, handled, transported, installed, and checked out at all times before launch, in accordance with procedures agreed to between LM, NRL, and the ELV launch site.

3.3.6.4 Discharge

The Instrument **shall** not present non-controllable health hazards associated with electrical discharge, ionizing or non-ionizing radiation, noise, or other emissions.

3.3.6.5 Documentation

Hazards **shall** be documented to provide a basis for reducing risk to an acceptable level, along with any necessary personnel protection procedures.

3.3.7 Computer Resources

3.3.7.1 Margins

Requirement deleted.

3.3.7.2 Specific Requirements

Requirement deleted.

3.3.8 Standards of Manufacture

3.3.8.1 Processes and Controls

The manufacturing processes and controls **shall** provide a baseline that ensures subsequent production items can be manufactured that are identical to, or better in performance, quality, and reliability than, initial production items used for qualification or flight demonstrations.

3.3.8.1.1 Documentation

For space equipment, these process controls **shall** be documented to give visibility to the procedures and specifications by which all processes, operations, inspections, and tests are to be accomplished. Internal documentation **shall** include the name of each component or part, each material required, the point it enters the manufacturing flow, and the controlling specification or drawing.

3.3.8.1.2 Tooling, Facilities, and Test Equipment

The documentation **shall** indicate required tooling, facilities and test equipment, the manufacturing check points, the quality assurance verification points, and the verification procedures corresponding to each applicable process or material listed.

3.3.8.1.3 Revisions

The specifications, procedures, drawings, and supporting documentation **shall** reflect the specific revisions in effect at the time the item(s) used for qualification were produced.

3.3.8.2 Production Lots

3.3.8.2.1 Grouping

Parts **shall** be grouped together in individual production lots during the various stages of their manufacture to ensure that all devices in a production lot are assembled during the same time period, using the same production materials, tools, methods, and controls.

3.3.8.2.2 Ordnance

Space equipment that cannot be adequately tested after assembly without destruction of the item, such as explosive ordnance devices, propulsion components, and complex electronics, **shall** have production lot controls implemented during manufacturing to ensure a uniform quality and reliability level of the entire lot.

3.3.8.2.3 Batches

Each production lot **shall** be manufactured and tested as a single batch.

3.3.8.2.4 Lot numbers

Lot numbers **shall** be assigned to each production lot.

3.3.8.3 Contamination Control and Cleanliness

The space segment flight elements **shall** be protected from contamination during fabrication, integration, testing, storage, handling, transportation, and at the launch base in accordance with the *FAME Instrument Contamination Control Plan (P5466114).*

3.3.8.4 Connectors

3.3.8.4.1 Keying

Connectors for Instrument external interfaces **shall** use keying or equivalent means to prevent mismating as practicable.

3.3.8.4.2 Alignment Markings

Connectors and connections **shall** have durable stripes, arrows, or other indications to show the positions of alignment pins or equivalent devices to prevent improper connection.

3.3.8.4.3 Unique Identification

Connectors **shall** be uniquely identified.

3.3.8.5 Positive Locking Devices

3.3.8.5.1 Screws

Screw-type hardware on the space segment **shall** employ positive locking.

3.3.8.5.2 Safety wiring

Safety wiring **shall** be in accordance with NASM33540.

3.3.9 Instrument Quality Factors

3.3.9.1 Quality Planning

The Reliability and Quality Assurance program **shall** be defined in the *FAME Instrument Product Assurance Implementation Plan (P546612).*

3.3.9.2 Reliability

As part of the design Process, a reliability analysis **shall** be performed on the Instrument using the guidelines of MIL-STD-1543 and the parts failure rates of MIL-HDBK-217.

3.3.9.2.1 Failure Propagation

As a goal, the Instrument design **shall** be such that a failure in one component does not propagate to other components.

3.3.9.3 Failure Modes and Effects Analysis (FMEA)

As part of the design process, an FMEA **shall** be performed on critical Instrument interfaces where a failure can propagate to loss of mission.

3.3.9.4 Single Point Failures

As part of the design process, mission critical SPF **shall** be identified and documented in the FMEA.

3.3.9.4.1 Single Point Failure Mitigation

As a goal, any SPF identified that causes a loss or serious degradation of the Instrument's on orbit mission **shall** be corrected through redundancy when practical and when in consonance with the program's schedule and cost constraints.

3.3.9.4.2 Critical Items List

Provisions **shall** be made when practical to enable monitoring of SPF that could give rise to critical or catastrophic hazards, or to mission loss of the Instrument data. All SPFs will be identified on the Critical Items List (CIL).

3.3.9.5 Electrical Stress Analysis

As part of the design process, an electrical stress analysis **shall** be performed on the Instrument using the derating criteria of GSFC 311-INST-001 grade 2, and MIL-HDBK-975.

3.3.9.6 Worst Case Analysis

As part of the design process for electrical and electronic subsystems, a worst case analysis (WCA) **shall** be performed at the component level for each "black box" deliverable of the Instrument.

3.3.9.6.1 Worst Case Analysis Mission Phases

The WCA **shall** prove that the item design will perform as expected during all phases of the mission.

3.3.9.6.2 EEE Part Parameters

The WCA **shall** address EEE part parameters and derating, provide a digital timing analysis for each clocked device, gate output loading, interface margins, asynchronous interfaces, reset conditions and state machine functions, part safety conditions [e.g. electrostatic discharge (ESD) considerations], cross-strap signals between redundant modules, and signal quality/levels across interfaces. The use of tailored guidelines of SSD-D-IM007 or IEEE-STD-1332-1998, as well as automated tools, logic simulations, or statistical methods is encouraged.

3.3.9.7 Redundancy

As part of the design process, redundancy options **shall** be identified, and adequate redundancy **shall** be provided, were practical, to eliminate single point failures (see Section 3.3.9.4) and to ensure the Instrument achieves its 5 year mission life requirement.

3.4 Documentation

Documentation **shall** be consistent with established operation practices except as tailored to meet specific Instrument requirements. The FAME Instrument documentation **shall** be consistent with LMSSO established practices.

3.4.1 Specifications

Design specifications related to the Instrument will be prepared in accordance with the guidelines of MIL-STD-961, *Specification Practices* and *FAME Instrument Software Management Plan (P546610)*. Documents will be subject to change control procedures and every proposed engineering change will consider the effect of that change on these documents so that compatibility is maintained.

3.4.2 Drawings

Performance and detailed specifications will be supported by drawings in accordance with the guidelines set forth in MIL-DTL-31000 for a Technical Data Package (TDP) or equivalents for Level 1 drawings per DoD-D-1000B, Drawings, Engineering and Associated Lists.

3.4.2.1 Minimum Information

Specifically, the engineering drawings and associated lists **shall**, as a minimum, disclose engineering design information sufficient to fabricate, inspect, and test developmental hardware.

3.4.3 Software Support Documentation

All software support documentation **shall** be prepared in accordance with the guidelines of *FAME Instrument Software Management Plan (P546610)*.

3.4.4 Test Plans and Procedures

All test plans and procedures will be documented so that skilled engineering personnel can accomplish testing of the system.

3.4.5 Systems Effectiveness Models

3.4.5.1 Structural Model

A design analysis or an analytical model **shall** be developed that correlates the primary structural modal frequencies below 50 Hz to within 5 percent of the experimental results. The analytical model, if used, should be written in NASTRAN or equivalent.

3.4.5.2 Thermal Model

Thermal models (SINDA85, TRASYS, or equivalent) **shall** be verified by test at the Instrument level.

3.5 Reserved

3.6 Reserved

3.7 Assembly Level Requirements

3.7.1 Optics

3.7.1.1 Fame Telescope System

3.7.1.1.1 In-scan Pointing (Basic Angle)

The surfaces of the two Compound Mirrors **shall** be oriented in the X-Y plane so that vectors normal to their reflecting surfaces subtend an angle 40.5° - 42.15°.

3.7.1.1.2 Cross-scan Pointing
The surfaces of the two Compound Mirrors **shall** be oriented so that the vectors normal to their reflecting surfaces lie in the X-Y plane to within ± 10 seconds of arc.

3.7.1.1.3 Aperture
The entrance apertures to the FAME Instrument **shall** be rectangular, 56 cm x 13 cm ± 0.1 cm.

3.7.1.1.4 Optical Quality
The optical quality of the starlight delivered to the FAME Focal Plane shall be < λ/18 (0.056λ) rms per aperture, where λ = 650 nm.

3.7.1.1.5 Field of View
The field of view of the FAME Instrument **shall** be ≥ 1.136°.

3.7.1.1.6 Focal Length
The focal length of the FAME Instrument **shall** be 15 m ± 0.1 m.

3.7.1.1.7 Spectrum
The FAME Instrument **shall** meet its requirements over a spectral band of 400– 900 nm.

3.7.1.1.8 Transmission Efficiency
The FAME Instrument **shall** meet its requirements while observing stars of magnitude $6 \leq m_v \leq 15$.

3.7.1.1.9 Distortion
The non-linear distortion of the FAME Instrument **shall** be < 10 microns.

3.7.1.1.10 Lateral Color
Lateral color introduced by the FAME optics **shall** be < 10 microns.

3.7.1.1.11 Field Curvature
The focus of the FAME Instrument **shall** be uniform over the field of view to < λ/40 rms, where λ = 6500Å.

3.7.1.1.12 Stray Light
The stray light flux incident on the FAME Focal Plane shall be less than that of a 15^{th} magnitude star when the center of the Earth is > 20° off axis from the center of either FAME field of view.

3.7.1.1.13 Optical Stability
TBD.

3.7.1.1.14 Transmission Uniformity
TBD.

3.7.1.1.15 # of Apertures
The FAME telescope shall have two apertures.

Flows from 3.2.1.1.

3.7.1.1.16 Polarization

TBD.

3.7.1.2 Active Secondary Mirror System

The Active Secondary Mirror System is defined to be the motors and mounts that actuate the Secondary Mirror, the laser diode fiber sources embedded in the FPA, and all required cabling and control electronics.

3.7.1.2.1 Actuation System

3.7.1.2.1.1 Resolution

3.7.1.2.1.1.1 Linear

The actuation system **shall** be capable of positioning the Secondary Mirror within its range to a resolution of < 0.25 microns.

3.7.1.2.1.1.2 Angular

The actuation system **shall** be capable of positioning the Secondary Mirror within its range to a resolution of < 2 seconds of arc.

3.7.1.2.1.2 Stability

3.7.1.2.1.2.1 Linear

When powered off, The actuation system **shall** hold the Secondary mirror in place to < 0.1 microns.

3.7.1.2.1.2.2 Angular

When powered off, The actuation system **shall** hold the Secondary mirror in place to < 0.2 seconds of arc.

3.7.1.2.1.3 Dynamic Range

3.7.1.2.1.3.1 Linear

The actuation system **shall** have a linear dynamic range in three axes of > 500 microns

3.7.1.2.1.3.2 Angular

The actuation system **shall** have a angular dynamic range in three axes of > 300 seconds of arc

3.7.1.2.1.4 Heat output

3.7.1.2.1.5 Power consumption

3.7.1.2.1.6 Focus Diodes

3.7.1.2.1.6.1 Nominal pulse

The duration of a nominal pulse of light from the Laser Diodes **shall** be 0 to 500 microseconds.

3.7.1.2.1.6.2 Pulse duration range

The Laser Diodes **shall** be capable of generating pulses of light up to 1000 microseconds.

3.7.1.2.1.6.3 Irradiance

3.7.1.2.1.6.4 Wavelength

The Laser Diodes **shall** emit light of wavelength $\lambda = 6700 \pm 300$ Å.

3.7.1.2.1.6.5 Power consumption

3.7.1.3 FPA Window

3.7.1.3.1 Anti-reflection coating

The front (concave) side of the FPA Window **shall** be coated with a broadband, anti-reflection coating with a reflectivity < 1% over the 400 – 900 nm band

3.7.1.3.2 Infrared Rejecting Coating

3.7.1.3.2.1 In-Band Transmission

Requirement deleted.

3.7.1.3.2.2 Out-of-Band Transmission

Requirement deleted.

3.7.1.4 CCD Filters

3.7.1.4.1 Astrometric

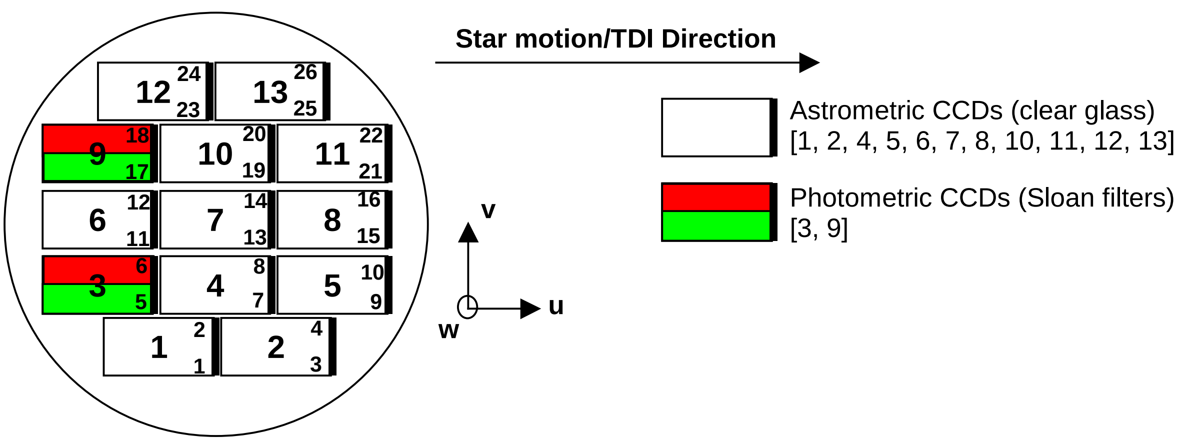


Figure 3-19: Location of Photometric and Neutral Density Filters

3.7.1.4.2 Photometric

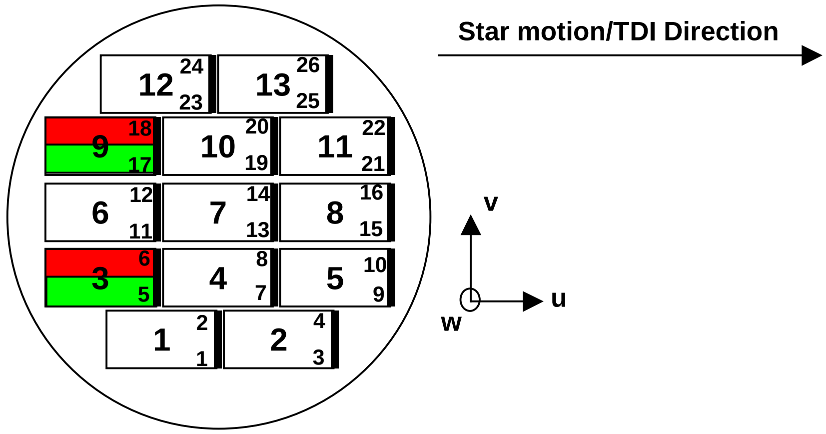


Figure 3-20: Layout of photometric filters

3.7.1.5 Flat Field

3.7.1.6 Alignment

3.7.2 Focal Plane Assembly

3.7.2.1 Mechanical

3.7.2.1.1 Baseplate

The focal plane assembly baseplate shall be designed to mount 24 2048 x 4096 CCDs within the image area defined by the 1.136° field of view and 15.017m focal length. Image area shall be a circle of diameter 297.61 mm.

3.7.2.1.2 Window Mount

The focal plane assembly shall provide a thermally stable mount for the focal plane window.

3.7.2.1.3 Radiator and Heat Exchanger

The focal plane assembly **shall** include a heat exchanger and radiator panel that attaches to the FPA in order to maintain the CCD maximum operating temperature.

3.7.2.1.4 Flexures

The focal plane assembly shall be mounted to the instrument primary structure using three flexures.

3.7.2.2 CCDs

3.7.2.2.1 CCD Interfaces

3.7.2.2.1.1 CCD to FPA Baseplate

3.7.2.2.1.2 CCD to Pre-amp Filter Board

3.7.2.2.1.3 Pre-amp Filter Board to Analog Processing Assembly

3.7.2.2.2 CCD Architecture

3.7.2.2.2.1 CCD Filter Support
The CCD package **shall** include supports for mounting of a filter cover slide 2 mm (TBR) above the imaging area.

3.7.2.2.2.2 Image Area
The FAME CCD **shall** have an image area of 4096 pixel rows x 2048 pixel columns.

3.7.2.2.3 Pixel Size
The physical, on CCD, image area pixel size **shall** be 15 µm (W) x 15 µm (L).

3.7.2.2.4 Array Flatness
The FAME CCD **shall** have an array flatness of +/- 20 µm.

3.7.2.2.4.1 Power Dissipation
Each CCD **shall** dissipate no more than 130 mw with a goal of dissipating no more than 100mw.

3.7.2.2.5 Vertical Register Performance Quantum Efficiency
Each CCD **shall** meet the required quantum efficiency specified in Column 2 of Table 3-11. As a goal each CCD **shall** meet the quantum efficiency specified in Column 3 of Table 3-11.

Table 3-10: Vertical Register Quantum Efficiency

Wavelength	Required	Desired
400 nm	≥60 %	≥70 %
500 nm	≥75 %	≥85 %
600 nm	≥80 %	≥90 %
700 nm	≥70 %	≥80 %
800 nm	≥50 %	≥60 %
900 nm	≥30 %	≥30 %

3.7.2.2.6 Output Amplifier Performance

3.7.2.2.7 Readout Noise
The output amplifier readout noise **shall** meet the requirements of Column 2 of Table 3-12 with the goal of meeting the desired values provided in Column 3.

Table 3-11: Output Amplifier Readout Noise

Frequency	Requirement	Goal
137KHz	$\leq 7e^-$ rms	$\leq 5e^-$ rms
3.3MHz	$\leq 15e^-$ rms	$\leq 10e^-$ rms

3.7.2.2.7.1 Conversion Gain

The output amplifier conversion gain **shall** be at least 2.0 x 10^{-6}V/e^-.

3.7.2.2.7.2 Linearity

The output amplifier response linearity **shall** not vary more than 5% from 4,000 e^- to 400,000 e^-.

3.7.2.3 Alignment

3.7.3 Structure

3.7.3.1 Primary Structure

3.7.3.1.1 Straylight

All interior components of the FIS **shall** have a specular reflectivity of < 3% and an absorptivity > 90% between 400 and 900 nm.

3.7.3.1.2 Optic Mounting Alignment Requirements

The structure shall provide means to attach the optical mounts.

3.7.3.1.3 Thermal Expansion

3.7.3.1.3.1 Component Parts

All structural components shall have in-plane absolute value of the coefficient of thermal expansion less than 0.3×10^{-6} m/m/°C.

3.7.3.1.3.2 Final Structure Assembly

The magnitude of any dimension change due to thermal expansion between the primary mirror mounting holes and the CMA mounting holes shall be less than 0.3×10^{-6} m/m/°C.

1.1.1.1.4 Moisture Expansion

3.7.3.1.4.1 Coefficient of Moisture Expansion

All structural components shall have in-plane coefficient of moisture expansion < 250 με/%M (microstrain / % moisture by mass)

3.7.3.1.4.2 Maximum Moisture Absorption

All structural components shall absorb < 0.3%M (% moisture by mass).

3.7.3.2 Baffles
Tertiary Mirror to Fold Flat 0 Mirror Tip Tilt Angle Stability

3.7.3.2.1 Aperture Baffles
The structure subsystem **shall** include aperture baffles for both of the Instrument apertures.

3.7.3.2.2 Internal Baffles
The structure subsystem **shall** include baffles around thefield lens assembly, the fold flat, and the focal plane.

3.7.3.3 Aperture Door Assemblies
The aperture doors will have an opening mechanism.

The baffles **shall** each have a door that will be closed during launch to protect the Instrument.

3.7.3.3.1 Open Once
The aperture door opening mechanism **shall** be designed to open only once during the mission and remain open for the duration of the mission.

3.7.3.3.2 Open Response Time
The aperture door mechanism **shall** open the door within 15 minutes of receiving a command from the Spacecraft Bus.

3.7.3.4 Focal Plane Assembly Monocoque
Requirement deleted.

3.7.3.5 Closeout panels
The structure subsystem **shall** include light-tight closeout panels that will prevent light from entering the instrument interior everywhere except for through the two entrance apertures.

3.7.3.6 Flexures
The structure subsystem shall provide three bipod flexure mounts to attach the instrument assembly to the spacecraft.

3.7.3.7 Alignment Cubes
The structure subsystem shall provide means to attach two alignment cubes.

3.7.3.8 Electrical boxes support
The structure subsystem **shall** include attachment interfaces and structural support for the Instrument ES&DP subsystem.

3.7.3.9 Thermal blankets grounding
The structure subsystem **shall** provide ground attachment locations for the thermal blankets.

3.7.3.10 S/C interface
The structure **shall** provide a three point mechanical interface to the S/C bus as defined in the *S/C to Instrument ICD*.

3.7.3.10.1 S/C antenna support

The structure subsystem **shall** include attachment interfaces and structural support for an antenna and mounting bracket to be supplied and integrated (TBR) by NRL. This interface **shall** be fully described in the *S/C to Instrument ICD.*

3.7.3.10.2 S/C antenna harness support

The structure subsystem **shall** include attachment interfaces and structural support for the antenna wiring harness to be supplied and integrated (TBR) by NRL. This interface **shall** be fully described in the *S/C to Instrument ICD.*

3.7.3.10.3 S/C star tracker support

The structure subsystem **shall** include attachment interfaces and structural support for two star trackers and mounting brackets to be supplied and integrated by NRL. This interface **shall** be fully described in the *S/C to Instrument ICD.*

3.7.3.10.4 S/C star tracker harness support

The structure subsystem **shall** include attachment interfaces and structural support for the star tracker wiring harness(es) to be supplied and integrated by NRL. This interface **shall** be fully described in the *S/C to Instrument ICD.*

3.7.3.10.5 Cleanliness

The FIS shall be clean to level 300A and shall comply with the requirements of the FAME Instrument Contamination Control Plan *(P546614)*.

3.7.3.10.6 Load Induced Hyseresis

The FIS **shall** have structural hysteresis, as measured between any two points on the FIS, less than 0.0254 mm (0.001 inches) after a load is applied as shown in Drawing 5873003.

3.7.3.10.7 Vacuum Bakeout

The Instrument Structure **shall** undergo a thermal vacuum bakeout at 5.0×10^{-5} Torr or less at 70±5 °C for at least 72 hours. The certification bakeout at 30 °C will be monitored with a Thermal controlled Quartz Crystal Microbalance (TQCM) at -20 °C collection temperature to determine the rate of outgassing. The bakeout certification will be conducted until the rate of outgassing stabilizes and the TQCM indicates a rate of outgassing of less than 3.0×10^{-11} g/cm^2/hour. The vacuum chamber will be equiped with a Residual Gas Analyzer (RGA) to measure the consituents of the outgassing.

3.7.4 Thermal Control

3.7.4.1 Focal plane assembly

3.7.4.1.1 Operating temperature

The thermal control subsystem **shall** maintain the temperature of the CCDs in the FPA at less than -80° C during operation.

The CCDs must be operated at low temperatures to reduce the dark current and mitigate the increase in CTI due to radiation damage.

3.7.4.1.2 Survival/Nonoperating Temperature

The thermal control subsystem **shall** maintain survival temperatures of the FPA between –140 °C and +70 °C

3.7.4.1.3 Temperature Gradient Stability

The temperature of the FPA substrate **shall** vary by less than 0.04° C/second, except for during eclipse and the three hour period following eclipse.

The gradient stability is estimated based on the 1/350th pixel centroiding requirement.

3.7.4.2 Truss Structure

3.7.4.2.1 Operating Temperature

The thermal control subsystem **shall** maintain the Instrument truss structure temperature at 17 ±5 °C during operation.

3.7.4.2.2 Survival/Nonoperating Temperature

The thermal control subsystem **shall** maintain the survival temperatures of the truss structure temperature between –40 °C and +70 °C.

3.7.4.2.3 Temperature Gradient Stability

The Instrument truss structure temperature gradient **shall** vary by no more than 3.333×10^{-6} °C/second (TBR), except for during eclipse and the three hour period following eclipse.

The gradient stability is derived from the basic angle stability requirement using OTM results.

3.7.4.3 Optics

3.7.4.3.1 Operating Temperature

The thermal control subsystem **shall** maintain the reflective TBR) temperatures at 17±5 °C during operation.

The operating temperature is derived from the optics wavefront error requirement using OTM results.

3.7.4.3.2 Optics Survival/Nonoperating Temperature

The thermal control subsystem **shall** maintain the survival temperatures of the reflective optics (compound mirrors, primary, secondary, tertiary, fold flats 0-4) between –40 °C and +45 °C.

3.7.4.3.3 FPA Window Operating Temperature

The thermal control subsystem **shall** maintain the FPA window temperature at (TBD) °C during operation.

3.7.4.3.4 FPA Window Survival/Nonoperating Temperature

The thermal control subsystem **shall** maintain the survival temperature of FPA window between (TBD) °C.

3.7.4.3.5 Focus Adjust Mechanism Operating Temperature

The thermal control subsystem **shall** maintain the focus adjust mechanism temperature at (TBD) °C during operation.

3.7.4.3.6 Focus Adjust Mechanism Survival/Nonoperating Temperature

The thermal control subsystem **shall** maintain the survival temperature of focus adjust mechanism between (TBD) ^{o}C.

3.7.4.3.7 Compound Mirror Temperature Gradient Stability

The compound mirror temperature gradient **shall** vary by no more than 3.333×10^{-6} °C/second (TBR), except for during eclipse and the three hour period following eclipse.

The temperature of the compound mirror needs to be maintained at a stable or smoothly varying temperature over time scales of 10 to 40 minutes. What are important are the residuals from fitting a sinusoid with a period of 24 hours *to the variation in basic angle. The gradient stability applies to short time scales (~10 minutes) and is derived from the basic angle stability requirement using OTM results.*

3.7.4.3.8 Primary Mirror Temperature Gradient Stability

The primary mirror temperature gradient **shall** vary by no more than TBD °C/second, except for during eclipse and the three hour period following eclipse.

The gradient stability is derived from the basic angle stability requirement using OTM results.

3.7.4.3.9 FPA Window Temperature Gradient

The FPA window temperature gradient **shall** be no more than 2 °C (TBR).

Lynn to provide comment on derivation of this requirement?

3.7.4.3.10 Focus Adjust Mechanism Temperature Stability

The focus adjust mechanism average temperature **shall** vary by no more than (TBD) °C/second except for during eclipse and the three hour period following eclipse.

The operating temperature is derived from the optics wavefront error requirement using OTM results.

3.7.4.4 Electronics

3.7.4.4.1 Operating Temperature

The thermal control subsystem **shall** maintain the electronics box (APAs, DPA) at temperatures between –40 and +50 °C (TBR) during operation.

3.7.4.4.2 Survival/Nonoperating Temperature

The thermal control subsystem **shall** maintain the survival temperatures of the electronics boxes between –55 °C and +70 °C.

3.7.4.5 Aperture Door Operating Temperature

The thermal control subsystem **shall** maintain the aperture door temperatures between –70 and +60 °C (TBD).

3.7.5 Electronics

3.7.5.1 CCD Control

3.7.5.1.1 Charge injection

The instrument electronics shall be capable of injecting charge into the CCD to 10 bits accuracy over the range from 1000 e- to 100,000 e-.

3.7.5.1.2 CCD clocking mode

The electronics shall only clock the CCDs in Time Delay and Integration mode. The nominal TDI rate shall clock a star down the CCD columns in 2.24 seconds ± 10 %.

3.7.5.1.3 Reading and digitizing CCD signals

The instrument electronics shall clock all 13 FAME CCDs simultaneously, however, the charge injection, and binning modes and bin locations shall be independently controlled for each CCD half.

3.7.5.2 Processing

Requirement deleted.

3.7.5.3 Communications interfaces
Communications interfaces to meet the test, operational and survival requirements of the FAME instrument.

3.7.5.4 Instrument electronics configuration
The Instrument electronics shall be divided into three assembly types

Focal Plane Assembly Electronics
Analog Processor Assembly, APA
Data Processor Assembly, DPA

3.7.5.5 Focal Plane Assembly Electronics

3.7.5.5.1 Electronic Noise
The electronic read noise of the detector system **shall** be ≤ 13.3 e- for binned by 24 windows.

This requirement flows directly from 3.2.1.15.

3.7.5.5.2 Pre-amplificaton and Bias Filtering
The PreAmp/Filter boards shall provide bias filtering and CCD signal pre-amplification.

3.7.5.6 Analog Processing Assembly

3.7.5.6.1 CCD clocking and charge injection
The analog processor shall provide all clock drivers, biases, charge injection signals needed to operate the 13 CCDs in the FPA.

3.7.5.6.2 Analog signal chain
The analog processor shall also provide two selectable amplifier gain settings and CCD output signal digitization to 14 bit accuracy, digital correlated sampling and a binned accumulator that can accommodate up to 64, 14 bit word, samples.

3.7.5.6.3 APA Data Handling
The APA shall also provide data formatting, housekeeping data, data multiplexing and transmission to the DPA.

3.7.5.6.4 Power input
The power input for the APA shall be the spacecraft 30±6 Vdc bus distributed by the DPA. All secondary voltages required for APA operation shall be generated within the APA.

3.7.5.6.5 Artificial star injection EGSE interface
The APA shall receive digital signals from EGSE to the charge injection circuitry for the purpose of injection “stars” into the CCD arrays. The EGSE interface shall be on a separate connector on the APA. When not in use this connector must have a conductive locking cap

3.7.5.6.6 Command and timing interface from the DPA
Clock timing signals for the APA shall be received from the DPA camera control board

3.7.5.6.7 APA ⇔DPA interfaces
All digital interfaces between the APA and the DPA shall be Low Voltage Differential Signals.

3.7.5.6.8 CCD clock generation
The APA shall develop, from the Master Oscillator, CCD common and CCD unique clocks, A/D converter timing and accumulator control clocks, and Charge injection data and clocks

3.7.5.6.9 Timing Accuracy

3.7.5.6.9.1 Frequency
The Instrument **shall** use a 50 MHz oscillator.

This requirement flows directly from 3.2.1.16.1.

3.7.5.6.9.2 Stability
The Instrument **shall** use an oscillator stable to $\leq 2.0\times10^{-10}$ over 1000 s.

This requirement flows directly from 3.2.1.16.2.

3.7.5.6.9.3 SC-Cut Crystal
The Instrument **shall** use an oscillator with a stress compensated cut crystal.

This requirement flows directly from 3.2.1.16.3.

3.7.5.7 Data Processing assembly

3.7.5.7.1 CCD clock generation
Requirement moved to 3.7.5.6.8.

3.7.5.7.2 Housekeeping data
The DPA shall measure temperature and voltage housekeeping data for addition to the instrument output data stream.

3.7.5.7.3 Primary computer
Requirement deleted.

3.7.5.7.4 Master Oscillator
Requirement moved to 3.7.5.6.9.

3.7.5.7.5 Star catalog EEPROM
Requirement deleted.

3.7.5.7.6 Heater Control
The DPA shall provide heater control for the following heaters: Closeout panels, Baffle, FPA, and Survival.

3.7.5.7.7 Closeout panel and baffle heaters
The Closeout panel and baffle heaters shall be regulated using Pulse Width Modulation Proportional Control

3.7.5.7.8 FPA heaters
The FPA heaters shall be regulated using linear proportional control

3.7.5.7.9 Power distribution
The DPA shall distribute 30 Vdc S/C power to the APA.

3.7.5.7.10 Focus motor commanding
The DPA electronics shall be able to control five stepper motors used for focussing the instrument.

3.7.5.7.11 Optical stimuli control
The DPA electronics shall be able to the operate 12 flat-field LEDs and the nine laser diode focus stimuli (TBR).

3.7.5.7.12 Spacecraft data interfaces.
The electrical interface between the Instrument and S/C is shown in Figure 3-41. Details of the electrical interface shall be defined in *FAME Spacecraft Bus to Instrument Interface Control Document (NCST-ICD-FM001).*

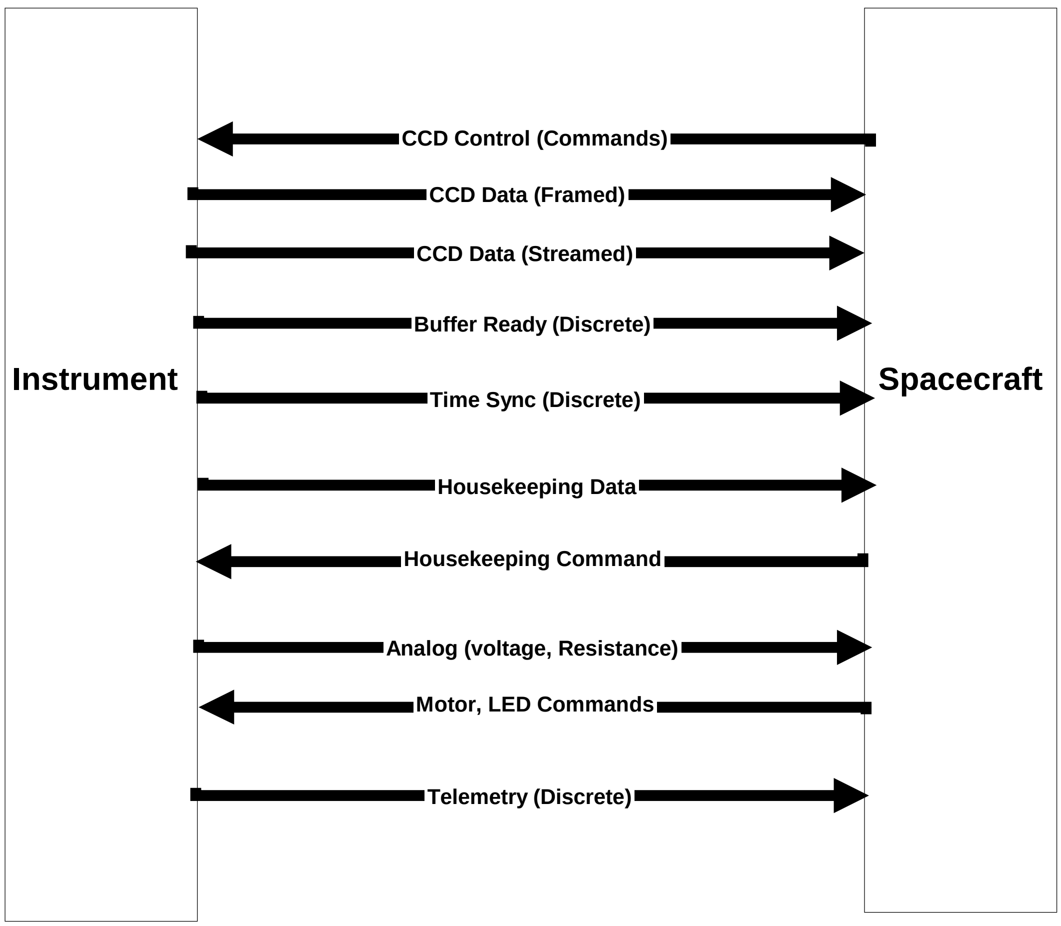


Figure 3-21: Instrument to Spacecraft Data Interfaces

3.7.5.7.13 Power input
The power input for the DPA shall be the spacecraft 30±6 Vdc bus. All secondary voltages required for DPA operation shall be generated within the DPA.

3.7.6 Software

4 REQUIREMENTS DELETED. QUALITY ASSURANCE PROVISIONS

4.1 General.

This section describes the analyses, tests, and inspections required for the FAME Instrument verification process. Verification of FAME Instrument design, construction, and performance will assure that the hardware and software conform to the requirements stated herein. LMSS will implement a quality assurance program according to the requirements of *Performance Assurance Implementation Plan for the FAME Program (P546612)*, to verify compliance with specified requirements.

4.2 QA Requirements.

4.2.1 Certification of Flight Quality Material.

LMSS **shall** provide all certifications, qualifications and exceptions for flight parts and material upon request. This documentation **shall** be available for inspection at LMSS for 5 years after the delivery of the Instrument to NRL.

4.2.2 Control of Nonconforming Material.

LMSS **shall** use internally developed and controlled procedures for control of nonconforming material as defined in *Performance Assurance Implementation Plan for the FAME Program (P546612)*. Nonconforming material **shall** not be used without approval. All non-conforming material used in the final product **shall** be adequately documented per *Performance Assurance Implementation Plan for the FAME Program (P546612).*

4.3 Product Verification

4.3.1 Verification Methods

The following text is derived from Section 3.3.2.2 of the *LMSSC-MSO Product Development Verification Guidebook*.

4.3.1.1 Test

Verification by test is the quantitative measurement of performance data or functional characteristics by applying functional, electrical or mechanical stimuli or exposure to a natural or induced environment to determine compliance with specified requirements. It typically includes collecting and evaluating performance data or functional characteristics by acquiring quantitative data through technical means and documenting the results.

4.3.1.2 Demonstration

Verification by demonstration is the exercise of the hardware, software or operation to ensure that quantitatively specified functions can be performed. Demonstration generally does not require special equipment or sophisticated measuring Instruments.

4.3.1.3 Analysis

Verification by analysis uses techniques such as statistical or quantitative analysis, computer simulations and analog modeling to complete calculations or make comparisons confirming that a product design satisfies functional, performance, interface or design requirements. Analysis results should prove that the product design provides the functional or performance capability, margin and design features specified for a product.

Verification by Similarity - This is a variant of verification by analysis in which analyses show that an article is identical or similar in design, manufacturing processes and quality control to another article that has been qualified by test to equivalent or more stringent criteria.

4.3.1.4 Inspection

Verification by inspection is the examination of a product's physical (not functional) characteristics to ensure compliance with the workmanship, quality, physical condition and dimensional tolerance requirements stated in a requirements document. Inspection includes simple measurements such as mass, power, current, resistance, size, location, etc. Inspection includes visual confirmations that special design or construction features required by the released engineering are compliant. Inspection also includes comparing software requirements or mechanization equations to program source listings or flow diagrams to verify software or database compliance with the software requirements.

Inspection uses standard quality control methods such as gauging, simple physical manipulation, and aided and non-aided visual inspection techniques. Inspection techniques do not require the use of special product-unique laboratory equipment, procedures or services.

4.3.1.5 Verification by Review

Verification by the review of design documentation is a method of verification that consists of a systematic review of design documentation to determine compliance with a requirement.

4.3.2 Verification Level

Verification levels are those hardware levels used to identify discrete verification activities. All verification of the FAME Instrument requirements delineated in Section 3 **shall** be performed as specified in the Verifications Matrix.

4.3.2.1 Component.

A component is a functional unit that is viewed as an entity for the purposes of analysis, manufacturing, maintenance, or record keeping. Examples include actuators, valves, and individual "black boxes".

4.3.2.2 Assembly

An assembly is a combination of items (components, structures, and interconnections) that perform a major task. Major FAME Instrument subsystems are listed in Section 3.7.

4.3.2.3 Instrument

The Instrument is an integrated set of all subsystems, components, and interconnections that form the complete flight item.

4.4 Performance Verification

The verification of functional and performance requirements provided in Section 3 of this specification will be specified in the FAME Requirements Verification Plan, P546617. The information provided below is derived from that plan and is provided here for reference.

4.4.1 Software Verification

Software requirements will be verified prior to installing flight software (computer programs) onto the instrument data processing hardware. The details of this effort are provided in the Software Development Plan.

All computer programs performing on-line mission-critical operational functions in any FAME instrument subsystem will be subject to an independent verification and validation (IV&V).

4.4.2 Instrument Level Verification

The following paragraphs summarize the test and demonstration activities of the FAME Instrument program details of the Integration and Test efforts are provided in the FAME Instrument Integration Plan, P546615 and the FAME Instrument Test Plan, P546616.

4.4.2.1 Performance and Functional Tests

4.4.2.1.1 Instrument Characterization

At the start of Acceptance Testing, the instrument will undergo a comprehensive performance test designed to verify compliance to every requirement that is testable at the instrument level. This is the most complete test and characterization of instrument performance. It includes additional characterizations of instrument performance that must be established at the start of Instrument level testing. The test must be executed with the instrument and GSE in a thermal vacuum chamber.

The test will be run only once in the test sequence shown below. This test and the requirements to be verified during it will be defined in the FAME Verification Plan.

4.4.2.1.2 Full Functional Performance Test

The test verifies compliance with the functional and performance requirements at several points in the test sequence. It is a subset of the Instrument Characterization test in that it does not repeat some of the detailed performance characterizations of that test. The test must be executed with the instrument and GSE in a thermal vacuum chamber as shown in the test sequence below.

4.4.2.1.3 Ambient Functional Performance Test

This test is a subset of the Full Functional Performance Test that includes only those tests which can be run in the ambient lab atmosphere. It is performed before and after each environmental test and is the last test performed before shipping the instrument to NRL for Observatory integration. The sequence of tests include, power-on, states and modes, electrical stimulation of the FPA (using charge injection), optical stimulation of the telescope using LEDs external to the FPA, and a focus test which verifies the optical state-of-health.

4.4.2.1.4 Random Vibration

The FAME instrument will undergo a 2-axis (x and y) test of the instrument according to the levels defined in Section 3.2.4.3.2.2 of this specification.

Testing **shall** be conducted with the instrument secured at its mounting locations to the shaker armature using a test fixture or fixture combination. Random vibration **shall** be applied to the instrument in each of axes. Vibration **shall** be measured and controlled with an accelerometer mounted on the vibration test fixture near one of the instrument mounting points. At the completion of the test, the instrument **shall** be visually examined for evidence of damage or permanent deformation.

4.4.2.1.5 Thermal Balance/Thermal Vacuum Tests

The validity of the FAME Instrument thermal design and Thermal Model **shall** be demonstrated by subjecting it to a thermal balance test. During this test the instrument shall be configured and operating in its “Operational Mode”. This test **shall** occur at 3 temperatures and may be combined with the Thermal-Vacuum Test.

The IPS **shall** be subjected to a 4 1/2 cycle thermal-vacuum test. The test **shall** commence with a “hot” cycle and **shall** conclude with a “hot” cycle. The temperature levels required for verification of the Instrument **shall** be as specified in Section 3.2.6.2.1 of this specification. The pressure **shall** be $5x10^{-6}$ torr ($6.64x10^{-4}$ Pascal’s) or less. Each cycle **shall** include a 4-hour soak (TBR) at the high and low-temperature levels. Functional Performance tests **shall** be conducted for at the extremes of the operating temperature range during the first and last thermal cycles, following the Hot and Cold starts, and during one Hot-to-Cold and one Cold-to-Hot transition. The transition between extreme temperature levels **shall** be made at a maximum rate of 20.0° C per hour. The last three cycles **shall** be failure free (TBR).

4.4.2.1.6 Outgassing Verification

Verification of the instrument outgassing rate **shall** occur by test at vacuum with the instrument at its highest operational temperature +10ºC. Outgassing levels for each subsystem **shall** be in accordance with the requirements defined in the *FAME Instrument Contamination Control Plan (P546614)*. This verification can be included as part of the subsystem Thermal-vacuum testing.

The outgassing test **shall** incorporate a quartz crystal microbalance (QCM) and cold finger during outgassing testing or an equivalent method. During Outgassing testing the TQCM **shall** be held at 10°C below the minimum on-orbit operating temperature of the instrument.

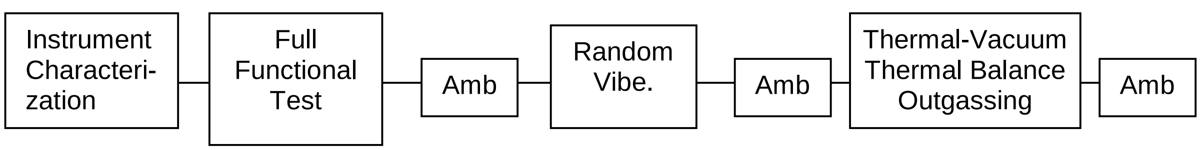
4.4.2.1.7 EMC/EMI

EMC/EMI testing consisting of tests for radiated emissions, conducted emissions, and conducted susceptibility (TBR) will be conducted on a subset of the instrument components. This subset consists of the monocoque shell and the FPA Subsystem.

4.4.2.2 Test Sequence

The sequence of test described in the section above is provided in Figure 4-1.

Figure 4-1. FAME Instrument Test Sequence



4.4.3 Instrument Level Reviews and Documentation

The results of each test will be provided, in detail, in a test report. The results of subsequent analysis may be provided in a separate Engineering Memo if the analysis methods and /or results are sufficiently complex or require independent evaluation.

All results will be made available at the Instrument Pre-Ship Review for examination and as proof of verification. The Test Reports, Engineering Memos and supporting documentation will become a part of the Acceptance Data Package to be complied by the FAME Quality Engineer.

4.4.4 Characterization Requirements

The requirements in this section derive from the MO&DA requirements for the mission. The requirements are for tests to be performed at the subsystem or instrument level to provide characterization data for the data analysis team.

The following characterization tests **shall** be performed and the data from these tests will be provided to the MO&DA team.

4.4.4.1 Bias

5 PREPARATION FOR DELIVERY

5.1 Instrument Configuration

5.1.1 Instrument Electrical Connectors

5.1.1.1 Door Safe Plugs

The Instrument Aperture Door Actuator electrical connectors shall be terminated with ‘ Safe’ grounded connectors.

All ‘Safe’ Connectors shall have a red ‘Remove Before Flight’ tag with serial numbers.

5.1.1.2 Instrument Electronic Connector Covers

All Instrument electrical cables terminating at the Instrument Interface Panel shall be terminated with a ‘Remove before flight’ ESD connector covers.

5.1.2 Instrument Protective Covers

5.1.2.1 Aperture Door Protective Covers

The Aperture Door Latch Assembly shall have protective covers installed.

5.1.2.2 Radiator Panel Protective Covers

The Instrument Radiator panel shall have a protective cover installed when not required for Instrument performance.

5.1.2.3 Instrument Alignment Cube Covers

The Primary Instrument Alignment Cube (IACp) and the secondary Instrument Alignment Cube (IACs) shall have protective covers installed.

5.1.3 Contamination Control

5.1.3.1 Instrument exterior surface

The Instrument shall be double bagged with a protective layer of transparent, cleanroom compatible material to prevent contamination during transit.

5.1.3.2 Purge

The Instrument bag shall provide access for a continuous internal purge.

5.2 Shipping Container Requirements

5.2.1 Internal Volume:

The Container shall have an internal volume greater than 60” high, x 84” x 90”.

5.2.2 Cleanliness

The container internal surface shall be certified to cleanliness level of 1000A or better.

5.2.3 Purge Gas

5.2.3.1 Container Purge Gas

The Transportation container shall provide HEPA filtered purge gas to the container interior volume.

5.2.3.2 Instrument Purge

5.2.3.2.1 Purge Gas Quality

The purge gas shall be composed of clean , dry, air or equivalent.

5.2.3.2.2 Instrument Purge gas connection

The Instrument Purge gas shall be connected through the transportation container base.

5.2.3.2.3 Container Purge Removal

Removal of the container cover shall not require the Instrument purge to be disconnected when the container cover is removed.

5.2.3.2.4 Instrument Purge gas supply

The shipping container shall provide an uninterrupted supply of instrument purge gas to transport the Instrument from LMMS to NRL.

5.2.4 Payload Mass

The Instrument shipping container shall be designed to support 336 kg.

5.2.5 Environmental Controls

5.2.5.1 Temperature

The shipping container shall maintain an internal temperature of 20±2.2ºC.

5.2.5.2 Relative Humidity

The shipping container shall control the Relative Humidity to 35%< relative humidity <50%.

5.2.5.3 Vibration

The Instrument shall be subjected to loads < 3gs in three axes when transported between the LMSS and NRL locations.

5.2.5.4 Shock

The internal instrument vibration isolation platform shall mitigate all shock events to less than the vibration levels defined in 5.2.5.3.

5.2.5.5 Vibration Monitors

5.2.5.5.1 Vibration Monitor

The Shipping container shall record the vibration environment on the isolation platform through the entire duration to transport the instrument. This monitor shall provide an electronic readout of the collected data for analysis.

5.2.5.5.2 Relative Humidity

The shipping container shall record the relative humidity of the shipping container internal volume through the duration to transport the Instrument. This monitor shall provide an electronic output for analysis to be provide at the conclusion of each transportation cycle.

5.2.5.5.3 Shock Indicators

One-shot, 5G, shock indicators shall be adhered to the shipping container isolation platform and the exterior surface of the Container along all three axes.

5.2.6 Transport method

The shipping Container with the Instrument shall be capable of being transported by ground or air.

5.2.7 Transport Container Portability

The transport container shall be removable from the trailer, equipped with wheels to accommodate integration of the Payload from within a class 10,000 clean room.

6 NOTES

6.1 Definitions

Basic Angle	The angle between the two telescope fields of view measured in a plane perpendicular to the rotation vector of the space vehicle.
Blocked Column	Columns in which a blockage or trapping are sufficiently severe in the CCD during the manufacturer's characterization that low-level signal charge cannot be transferred out regardless of the applied level of charge injection. Such columns should be readily apparent during Fe55 testing.
Charge Injection	Columns in which charge transfer efficiency is good (normal) as determined by Fe55 testing, Blocked Columns and optical response is good (normal) at any level of illumination, but the level of charge injection is diminished by 5% relative to the response of undiminished columns. Such columns are detectable only by applying a charge injection.
Dark Column	Columns in which no charge transfer defects are present, but optical response integrated over the length of the column is diminished by 5%, measured at 50% FW, relative to the mean response of undiminished columns. Such columns will not be apparent during Fe55 testing, and require optical stimulation. Such columns presumably result from an optical defect in the surface or anti-reflection (AR) coatings of the CCD.
Hipparcos	An ESA astrometry mission that flew in the early 1990's.
Hot Columns	Columns in which charge is generated in the absence of optical stimulation that exceeds $20e^{-}$.
Observatory	The FAME Observatory is defined as the integrated space vehicle including the Instrument, Spacecraft Bus, and Sun shield/solar arrays.
Partially Blocked Columns	Columns in which blockage of charge takes place only after a threshold signal level is exceeded, but in which charge transfer is normal for signal levels less than that threshold. Such columns should not be apparent during Fe55 testing, and will require high-level optical stimulation to be detected.
Sun angle	The angle between the Sun direction and the rotation axis of the integrated space vehicle.
TBD	To Be Determined. The use of this term implies an "open" requirement issue which must be resolved prior to CDR.
TBR	To Be Released/To Be Resolved. The meaning should be clear in the context of the use. In both cases the use of this term implies an "open" requirement issue which must be resolved prior to CDR.
Trapped Columns	Columns in which one or more low-level traps are present in the CCD.

6.2 Acronyms and Abbreviations

µas	Micro-arcseconds
BC	Blocked Column
CCD	Charge Coupled Device
CIBC	Charge Injection Blocked Columns
COMSEC	COMmunications SECurity
CTE	Charge transfer efficiency
CTE	Coefficient of thermal expansion
CTI	Charge transfer inefficiency
CVCM	Collected Volatile Condensable Material
DC	Dark Column
DoD	Department of Defense
DPA	Destructive Physical Analysis
EEE	Electrical, Electronic, and Electromechanical
ELV	Expendable Launch Vehicle
ESD	Electrostatic Discharge
ES&DP	Electronics, software, & data processing
FAME	Full-sky Astrometric Mapping Explorer
FOV	Field of View
FPA	Focal plane assembly
FRACAS	Failure Reporting And Corrective Action System
FV	Flight Vehicle
GIDEP	Government-Industry Data Exchange Program
GSE	Government Supplied Equipment
GSFC	Goddard Space Flight Center, NAS
HC	Hot Columns
HMI	Human-Machine Interface
ICD	Interface control document
KSC	Kennedy Space Center
MAR	MIDEX Assurance Requirements
MIDEX	Medium Class Explorer
NASA	National Aeronautics and Space Administration
NSDS	NASA Software Documentation Standard
OSHA	Occupational Safety and Hazard Administration
PBC	Partially Blocked Columns

PRACA	PRoblem And Corrective Action
PCB	Printed Circuit Board
PIND	Particle Impact Noise Detection
PMO	Project Management Office
PMP	Parts, Materials and Processes
PPL	Preferred Parts List
PSF	Point spread function
QPL	Qualified Parts List
QML	Qualified Manufacturer List
TBD	To Be Determined.
TBR	To Be Released/To Be Resolved
TC	Trapped Columns
TDI	Time Delay Integration
TML	Total Mass Loss

6.3 List of Open Items

Table 6-1: Open Requirements and Issues

Paragraph No.	Title	Information Required	Assigned to	ECD