NAVAL RESEARCH LABORATORY

NAVAL CENTER FOR SPACE TECHNOLOGY

Full-Sky Astrometric Mapping Explorer (FAME)
Detailed Mission Requirements Document (MRD)

NCST-D-FM002 **15 March 2001**

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1.0 SCOPE

1.1 Identification. This document applies to the Full-Sky Astrometric Mapping Explorer (FAME) mission.

1.2 Purpose. This specification establishes the system performance design and test requirements for the space and ground segments of the FAME observatory. These requirements are the basis for the more detailed requirements to be included in the specifications for the individual elements of the FAME observatory, which include, but are not limited to, the spacecraft bus, the instrument payload, and related ground elements.

1.3 System Overview. The observatory will provide the positions, proper motions, parallaxes, and photometry of nearly all stars as faint as 15th visual magnitude with accuracies of 50 microarcseconds (μas) at 9th visual magnitude and 500 μas at 15th visual magnitude. Stars will be observed with the Sloan Digital Sky Survey g', r', i', and z' filters for photometric magnitudes. This is accomplished by a scanning survey instrument with a mission life of 2.5 years and an extended mission to 5 years. For more information about the FAME science objectives, refer to NCST-D-FM001, *FAME Science Requirements Document*.

1.4 Document Overview. This Mission Requirements Document (MRD) establishes the top level functional performance, design, manufacture, verification, and acceptance requirements for the FAME program. It also identifies and describes the characteristics, design, construction, documentation, logistics, personnel, training, subordinate elements, and qualification requirements for the FAME program. These performance requirements are derived from the functional decomposition and a hierarchical breakdown of capabilities and functions that FAME will perform. This document is organized as follows:

- Section 1.0, *Scope:* Purpose and contents of this document, and an overview of the FAME program.
- Section 2.0, *Referenced Documents:* A list of documents referenced in or required for use with this document.
- Section 3.0, *Requirements:* Section 3.2 defines the performance of FAME as a system.
  - Requirements in Sections 3.2.4 through 3.6 are constraints with which FAME shall comply.
  - Requirements in Section 3.7 define the performance of FAME's subsystems. Requirements in Section 3.7 are based on functions derived from the system performance defined in Section 3.2.
- Section 4.0, *Quality Assurance Provisions:* Details the tests to be conducted and the methods of test verification that will be employed.

The performance requirements herein are applicable during nominal operations, maintenance, or contingency events. Requirements for earlier or other staged events are noted. Each element-level requirement, unless otherwise noted, represents the required performance of the element from the time of its activation through end of mission life.

2.0 REFERENCED DOCUMENTS

2.1 Government Documents. The following documents of the exact issue shown form a part of this document to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this document, the contents of this document shall be considered a superseding requirement. Copies of specifications, standards, drawings, and publications required by suppliers in connection with specified procurement functions should be obtained from the contracting agency or as directed by the contracting officer. Documents beginning with the control number "SSD" and "NCST" are program documents controlled by the NRL.

2.1.1 Military Specifications.

Most active military specifications are available on-line from: http://astimage.daps.dla.mil/quicksearch/

Number	Title	Referenced in Paragraph No.
DoD-D-1000B	Drawings, Engineering and Associated Lists	3.4.2
MIL-DTL-31000	Technical Data Packages	3.4.2
MIL-M-38510	Microcircuits, General Specification for	3.3.1.2
NASM33540	Safety Wiring and Cotter Pinning	3.3.10.5

2.1.2 Military Standards.

Most active military standards are available on-line from: http://astimage.daps.dla.mil/quicksearch/

Number	Title	Referenced in Paragraph No.
MIL-STD-883E	Test Methods and Procedures for Microelectronics	3.3.1.2
MIL-STD-961D	Specification Practices	3.4.1
MIL-STD-975M(2)	NASA Standard Electrical, Electronic, and Electromechanical (EEE) Parts List	3.3.1.3
MIL-STD-1522A	Standard General Requirements for Safe Design and Operation of Pressurized Missile and Space Systems	3.3.1.5.2
MIL-STD-1543B	Reliability Program Requirements for Space and Launch Vehicles	3.2.3.3
MIL-STD-1576	Electroexplosive Subsystem Safety Requirements and Test Methods for Space Systems	3.7.1.1.1.4.1
MIL-STD-1686C	Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment	3.3.1.4

2.1.3 Military Handbooks.

Most active military handbooks are available on-line from: http://astimage.daps.dla.mil/quicksearch/

Number	Title	Referenced in Paragraph No.
MIL-HDBK-217F	Reliability Prediction of Electronic Equipment Available from: http://astimage.daps.dla.mil/quicksearch/	3.2.3.3
MIL-HDBK-1547A	Electronic Parts, Materials, & Processes for Space & Launch Vehicles	3.3.1.3

2.1.4 Other Publications.

Number	Title	Referenced in Paragraph No.
EWRR 127-1	Eastern and Western Range Regulation 127-1, Range Safety Requirements	3.3.1.5.2, 3.3.6, 3.7.1.1.1.4, 3.7.1.1.1.4.1

Number	Title	Referenced in Paragraph No.
GSFC 311-INST-001 Revision A	Instructions for EEE Parts Selection, Screening, and Qualification Available from: http://epims.gsfc.nasa.gov/ctre/parts/inst/prd.htm	3.2.3, 3.3.1.1, 3.3.1.2
GSFC-410-MIDEX-001	MIDEX Assurance Guidelines	3.2.5.2.2.3, 3.3.1, 3.3.1.2
GSFC-410-MIDEX-002	MIDEX Assurance Requirements (MAR)	3.3.9
MSFC-SPEC-522A	Design Criteria for Controlling Stress Corrosion Cracking	3.3.1.5.2, 3.3.1.5.6
NASA-STD-2100-91	NASA Software Documentation Standard Available from: http://satc.gsfc.nasa.gov/assure/docstd.html	3.3.9
NHB 2570.6A	NASA Radio Frequency Spectrum Management Manual	3.2.1.1.1.1.2
SP-R-0022	Vacuum Stability Requirements of Polymeric Material for Spacecraft Applications, Specifications for	3.3.1.5.1
SSD-D-IM007	ICM Worst Case Analysis	3.2.3.6, 3.3.1.3

2.1.5 NASA Technical Standards.

NASA Technical Standards are available on-line from: http://www.hq.nasa.gov:80/office/codeq/doctree/qdoc.pdf

Number	Title	Referenced in Paragraph No.
NASA-STD-8739.1	Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies	3.3.1.6.1
NASA-STD-8739.2	Workmanship Standard for Surface Mount Technology	3.3.1.6.1
NASA-STD-8739.3	Soldered Electrical Connections	3.3.1.4, 3.3.1.6.1
NASA-STD-8739.4	Crimping, Interconnecting Cables, Harnesses, and Wiring	3.3.1, 3.3.1.6.1

2.1.6 FAME Project Documents.

Available to registered users at http://www.pxi.com/fame

Number	Title	Referenced in Paragraph No.
LMSS P5873001	FAME Instrument Design Specification	3.1.4.1.1, 3.1.5
NCST-D-FM001	FAME Science Requirements Document	1.3, 3.2.1.1.1, 3.7.2.3.3
NCST-D-FM002	FAME Mission Requirements Document	
NCST-D-FM003	FAME Error Budget	
NCST-D-FM004	FAME Systems Engineering Management Plan (SEMP)	
NCST-D-FM005	FAME Product Assurance Plan	3.2.3, 3.3.1, 4.1, 4.2
NCST-D-FM006	FAME Safety, Reliability, and Quality Assurance (SR&QA) Plan	
NCST-D-FM007	FAME Contamination Control Plan	3.2.5.1.1, 3.2.5.1.2, 3.2.5.1.3, 3.3.10.3, 3.7.1.1.1.8
NCST-D-FM008	FAME Configuration Management Plan	
NCST-D-FM009	FAME Preliminary Safety Assessment	
NCST-D-FM010	FAME System Safety Implementation Plan (SSIP)	
NCST-D-FM011	FAME Failure Modes and Effects Analysis (FMEA)	3.2.3.1
NCST-D-FM012	FAME Preliminary EEE Parts List	
NCST-D-FM013	FAME Preliminary Materials List	
NCST-D-FM014	FAME Orbital Debris Report	

Number	Title	Referenced in Paragraph No.
NCST-D-FM015	FAME Space Segment Reliability Analysis	
NCST-D-FM016	FAME Ground Segment Description Document	
NCST-D-FM017	FAME Design Loads Analysis Plan	3.2.4, 3.2.5.2.1
NCST-D-FM018	FAME EMI/EMC Control Plan	3.3.2
NCST-ICD-FM001	FAME Instrument to Spacecraft Bus Interface Control Document	3.1.3.3, 3.7.1.1.2.18, 3.7.1.1.2.19
NCST-ICD-FM002	FAME Spacecraft Bus to Expendable Launch Vehicle Interface Control Document	3.1.3.1, 3.2.1.1.1.1.2, 3.2.2.1, 3.2.2.2, 3.2.5.2.1, 3.3.1.6.3
NCST-ICD-FM003	FAME Space to Ground Interface Control Document	3.1.3.2
NCST-ICD-FM004	FAME Instrument to Spacecraft Software Interface Control Document	
NCST-ICD-FM005	FAME Spacecraft Controller (FSC) Hardware to Software Interface Control Document	
NCST-S-FM001	FAME Spacecraft Bus Design Specification	3.1.3.1, 3.1.4.1.1, 3.1.5, 3.2.1.1.1.1.2
NCST-SDP-FM001	FAME Flight Software Development Plan	3.3.9, 3.4.1, 3.4.3, 3.4.4, 3.7.1.1.1.5
NCST-SDP-FM002	FAME Ground Software Development Plan	3.3.9, 3.4.1, 3.4.3, 3.4.4
NCST-SRS-FM001	FAME Flight Software Requirements Document	3.7.1.1.1.5
NCST-SRS-FM002	FAME Ground Software Requirements Document	
NCST-TP-FM001	FAME Test Plan	4.1, 4.3.8, 4.3.8.4.2.1 through 4.3.8.4.2.4, 4.3.8.4.3.1 through 4.3.8.4.3.7

2.2 Non-Government Documents. The following documents form a part of this MRD to the extent specified herein. Unless otherwise indicated, the issue in effect on the date of the invitation of bids or request for proposal shall apply. In the event of conflict between the documents referenced herein and the contents of this specification, this specification shall take precedence. Copies of specifications, standards, drawings, and publications required by suppliers in connection with specified procurement functions should be obtained from the contracting agency or as directed by the contracting officer.

2.2.1 Specifications. Not applicable.

2.2.2 Standards. Not applicable.

2.2.3 Other Publications.

Number	Title	Referenced in Paragraph No.
ANSI/J-STD-001	Requirements for Soldered Electrical and Electronic Assemblies	3.3.1.6.1
ANSI/J-STD-002	Solderability Tests for Component Leads, Terminations, Lugs, Terminals and Wires	3.3.1.6.1
ANSI/J-STD-003	Solderability Test Methods for Printed Wiring Boards	3.3.1.6.1
ANSI/J-STD-004	Requirements for Soldering Fluxes	3.3.1.6.1
ANSI/J-STD-005	Requirements for Soldering Pastes	3.3.1.6.1
ANSI/J-STD-006	Requirements for Electronic Grade Solder Alloys and Fluxed and Non-fluxed Solid Solders for Electronic Soldering Applications	3.3.1.6.1
EIA-625	Requirements for Handling Electrostatic Discharge Sensitive Devices	3.3.1.4
IEEE-STD-1332-1998	IEEE Standard Reliability Program for the Development and Production of Electronic Systems and Equipment Available from: http://standards.ieee.org/reading/ieee/std_public/description/td/1332-1998_desc.html	3.2.3.6
IPC-A-600D	Acceptability of Printed Wiring Boards Available from: http://www.ipc.org	3.3.1.6.1
IPC-D-275	Standard for PCB Design and Assembly Available from: http://www.ipc.org	3.3.1.6.1
IPC-FC-250	Performance Specification for Single and Double-Sided Flexible Printed Boards Available from: http://www.ipc.org	3.3.1.6.1
IPC-FC-250A-86	Specification for Single and Double-Sided Flexible Wiring Available from: http://www.ipc.org	3.3.1.6.1

2.3 Order of Precedence. In the event of a conflict between the text of this specification and the reference cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3.0 REQUIREMENTS

This section specifies the functional, performance, interface, logistic, quality factor, and design requirements[1] for the space segment of the Full-sky Astrometric Mapping Explorer (FAME) observatory and its subordinate system elements. Also included are the performance requirements for the observatory ground segment.

a. Note that brackets "[ ]" or "To Be Resolved" (TBR) are used within this section to denote preliminary parameter values or requirements subject to change.

b. The term "To Be Determined" (TBD) or is used to denote items under study where the final value or requirement is not known.

3.1 FAME Mission Requirements. The principal requirement for the FAME mission is to provide the positions, proper motions, parallaxes, and photometry of nearly all stars as faint as 15th visual magnitude with accuracies of 50 microarcseconds (μas) at 9th visual magnitude and 500 μas at 15th visual magnitude on a near-continuous basis by means of its scanning survey instrument. The resultant mission data will be stored and transmitted to the ground segment (network) on a nearly-continuous basis for 2.5 years (requirement) and up to 5 years (goal).

3.1.1 Mission Concept. The observatory will rotate at a rate of 0.025 revolution per minute, allowing the instrument apertures to observe stars along a spiral. The rotation axis of the observatory precesses around the sun vector to scan the whole sky. FAME uses a charge coupled device (CCD) array with high quantum efficiency to determine transit times while simultaneously observing many stars. The CCDs will be used in a time delay integration (TDI) mode to synchronize the charge transfer with the rotation of the S/C. An input catalog will be generated by the FAME Project Team and will be reviewed by the Science Team. The input catalog is required to "window" the pixel data. The catalog will be loaded onboard the observatory and the catalog will be reprogrammable after launch. Over the course of the 2.5-year mission, each of the $m_v \geq 9$ program stars will be scanned about 950 times. The data from all the targets will be analyzed in order to derive their positions, proper motions, parallaxes, and colors.

The baseline FAME mission is 2.5 years of continuous observations, interrupted only by orbit, attitude, and rotation adjustments, as necessary. The observations will include astrometric observations with the majority of CCDs, bright star observations through neutral density filters, and photometric observations through four filters. The instrument will observe 40,000,000 stars in the magnitude range $5 < m_v < 15$ with mission positional accuracies between 50 and 500 μas and photometry with millimagnitude accuracies. The parallaxes and proper motions will be of equivalent accuracy.

3.1.2 FAME Mission Diagram. Figure 3-1 shows a block diagram of the FAME mission. To accomplish the mission requirements, the FAME mission requires a space segment (flight vehicle) and a ground segment.

3.1.2.1 Flight Vehicle Description. The FAME flight vehicle (FV) consists of the mated FAME observatory and the interstage assembly (see Figure 3-2).

3.1.2.1.1 FAME Observatory. The FAME observatory consists of a spacecraft (S/C) bus and a single scanning survey instrument (referred to as instrument or payload [P/L] herein). The nominal operational configuration of the observatory and its subordinate system elements **shall** be capable of fulfilling the mission requirements defined herein.

3.1.2.1.1.1 S/C Bus. The S/C bus consists of the flight hardware/software required to support the P/L.

3.1.2.1.1.2 FAME Instrument Payload. The FAME instrument P/L consists of a scanning survey instrument with a single telescope looking at two fields of view simultaneously. The two fields of view will be imaged onto a single focal plane populated with CCDs. The CCDs will be clocked in TDI mode to accumulate stellar images as the observatory rotates.

3.1.2.1.2 FAME Interstage Assembly. The FAME interstage assembly consists of the mating structure between the Expendable Launch Vehicle (ELV) and the observatory. The interstage also houses the Apogee Kick Motor (AKM).

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1. Requirements define the required behavior of the observatory. Requirements are specified herein as "shall" or "must" sentences. Statements of fact are specified herein as "will" sentences. Guidance on preferred, but non-mandatory solutions are specified as "should" sentences.

3.1.2.2 Ground Segment. The ground segment: (i) transmits commands to the observatory; (ii) receives and and archives downlinked HS&T telemetry and science data; (iii) monitors and trends S/C bus and instrument HS&T data; and (iv) analyzes and reduces science data to produce mission science deliverables.

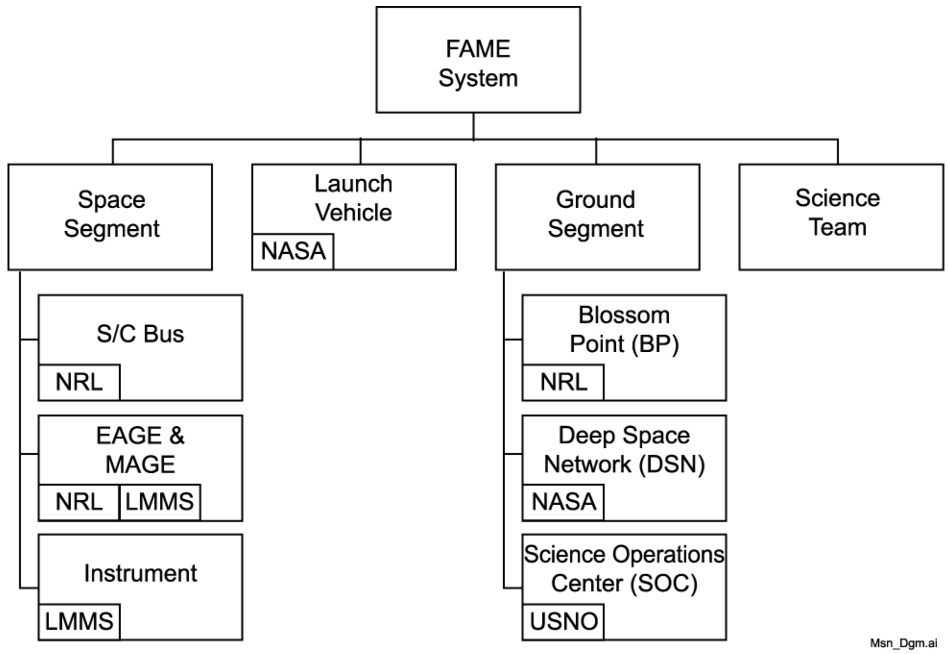

Figure 3-1. FAME Mission Diagram

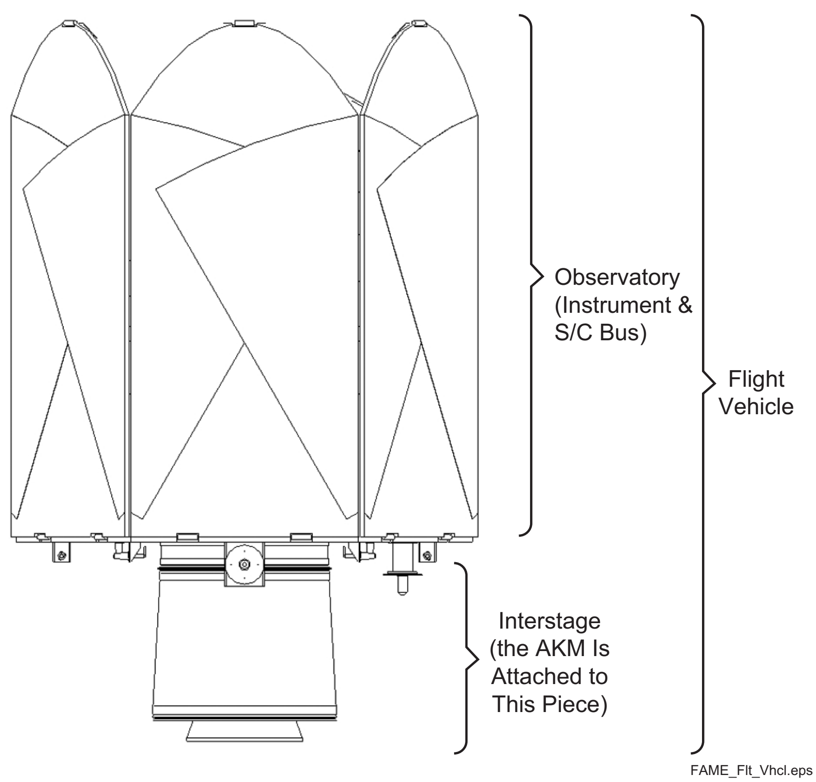

Figure 3-2. Space Segment Taxonomy

3.1.3 Interface Definition and Requirements. The interfaces defined in this document consist of mechanical, electrical, radio frequency (RF), thermal, command, and data (telemetry) interfaces external and internal to the space segment. The external interfaces will be specified and controlled through the applicable Interface Control Documents (ICDs), specifications, or engineering drawings as referenced throughout this document.

3.1.3.1 Flight Vehicle to ELV Interface. The interface between the FV (consisting of the AKM, the S/C bus, and the P/L) and the ELV will be described in the FAME S/C Bus Design Specification (NCST-S-FM001) and defined in the FAME S/C Bus to ELV ICD (NCST-ICD-FM002).

3.1.3.2 Space Segment (Flight Vehicle) to Ground Data System Interface. The observatory will have interfaces with BPTF MOC and NASA DSN for command, control, and communications (C^3). These interfaces will be defined in the FAME Space to Ground ICD (NCST-ICD-FM003).

3.1.3.3 Internal Interfaces. The FAME observatory has internal interfaces between the S/C bus and the instrument P/L. The interface between the S/C bus and the instrument P/L includes mechanical and electrical interface requirements. Mechanical interface requirements include items such as loads, Field of View (FOV), mounting, jitter, frequency, momentum interactions, mass, alignments, environmental, and thermal requirements. The electrical requirements include power, electromagnetic interference (EMI), mission data, and command/data links. These interfaces will be specified in the Instrument to S/C Bus ICD (NCST-ICD-FM001). Hardware Configuration Item (HWCI) to HWCI interfaces, HWCI to Computer Software Configuration Item (CSCI) interfaces, and CSCI to CSCI interfaces will be specified and controlled through ICDs, specifications, or engineering drawings.

3.1.4 Major Component List. The FAME system consists of the space segment (flight vehicle) and the ground segment (see Figure 3-3).

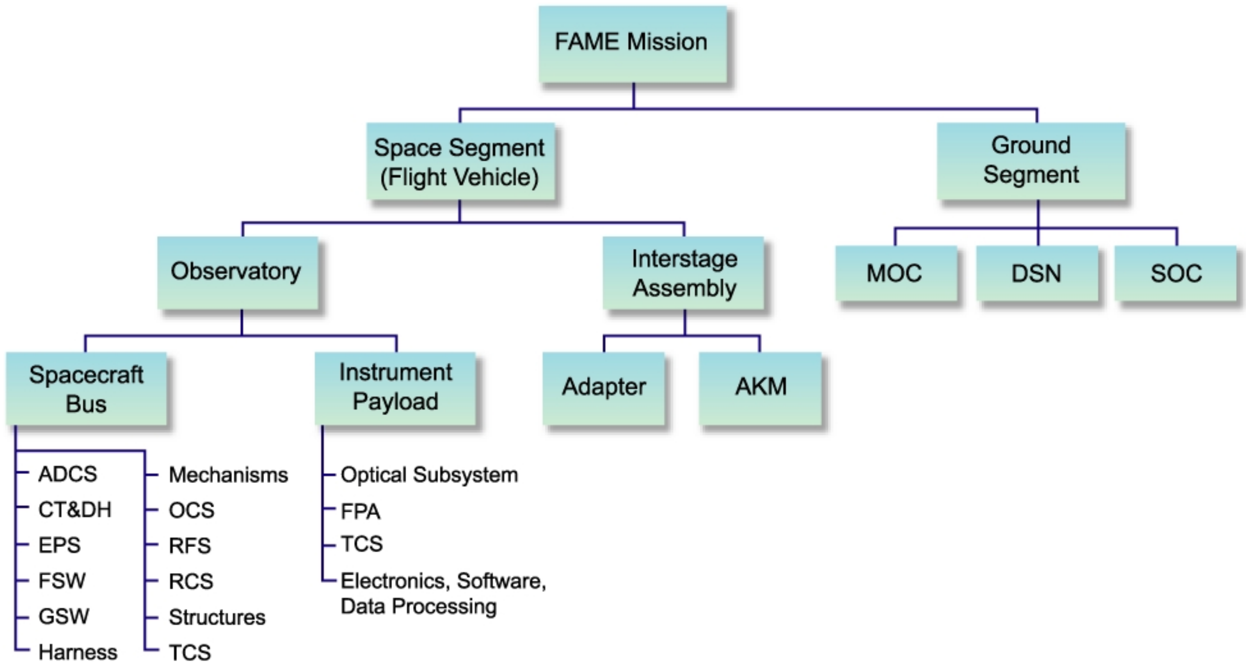

Figure 3-3. FAME Major Components

3.1.4.1 Space Segment (Flight Vehicle). The major components of the FV are the FAME observatory and the interstage assembly.

3.1.4.1.1 FAME Observatory. The major components of the FAME observatory are the S/C bus (NCST-S-FM001) and the instrument P/L (P5873001).

3.1.4.1.1.1 FAME S/C Bus. The major components of the FAME S/C bus are:

a. Attitude Determination and Control Subsystem (ADCS) (see paragraph 3.7.1.1.1.1)

b. Command, Telemetry, and Data Handling (CT&DH) Subsystem (see paragraph 3.7.1.1.1.2)

c. Electrical Power Subsystem (EPS) (see paragraph 3.7.1.1.1.4)

d. Flight Software (FSW) (see paragraph 3.7.1.1.1.5)

e. Ground Software (GSW) (see paragraph 3.7.1.1.1.6)

f. Harness (see paragraph 3.7.1.1.1.7)

g. Mechanism Subsystem (see paragraph 3.7.1.1.1.9)

h. Ordnance Control Subsystem (OCS) (see paragraph 3.7.1.1.1.4.1)

i. Radio Frequency (RF) Subsystem (see paragraph 3.7.1.1.1.10)

j. Reaction Control Subsystem (RCS) (see paragraph 3.7.1.1.1.11)

k. Structures Subsystem (see paragraph 3.7.1.1.1.12)

l. Thermal Control Subsystem (TCS) (see paragraph 3.7.1.1.1.13)

3.1.4.1.1.2 Instrument Payload. The major components of the instrument P/L are:

a. Optical Subsystem (see paragraph 3.2.1.1.1.2.1.1)

b. Focal Plane Assembly (see paragraph 3.2.1.1.1.2.1.2)

c. Structure (see paragraph 3.2.1.1.1.2.1.3)

d. Thermal Control Subsystem (see paragraph 3.2.1.1.1.2.1.4)

e. Electronics, Software, and Data Processing Subsystem (see paragraph 3.2.1.1.1.2.1.5)

3.1.4.1.2 Interstage Assembly. The major components of the interstage assembly are the interstage adapter and the AKM.

3.1.4.2 Ground Segment. The ground segment consists of the Mission Operations Center (MOC) and the Science Operations Center (SOC), supplemented by NASA's Deep Space Network (DSN) during early on-orbit operations.

3.1.5 Government Furnished Equipment List. The Government Furnished Equipment (GFE) and NASA Furnished Equipment (NFE) will be defined in the FAME S/C Bus Design Specification (NCST-S-FM001) and the FAME Instrument Design Specification (LLMS P5873001).

3.1.6 System Operations Concept. The following paragraphs describe the general operations activities occurring during the six mission phases, from prelaunch through disposal.

3.1.6.1 Pre-Launch Operations. The pre-launch phase begins with the arrival of the observatory and associated ground support equipment (GSE) at the launch site and ends with lift-off from the launch pad. Prior to integration with the ELV, the observatory will be fueled and mated with the AKM/interstage to form the Flight Vehicle (FV). The observatory will undergo interface inspection, analysis, or testing to verify compatibility with the ground segment and the ELV.

3.1.6.2 Launch and Ascent Operations. This phase starts with first motion and is complete with separation of the observatory from the Delta II 2425 Star-48 third stage. The S/C controller, sun sensor, receivers, and power control and distribution electronics (PCDE) will be powered during this phase. The S/C controller is preloaded with an event list that is activated by third-stage separation. All solar array panels are stowed during launch. The S/C ordnance control system (OCS) is "safed" and cannot be armed until after the S/C separates from the ELV. No ground station contacts are required during this phase.

3.1.6.3 Geosynchronous Transfer Orbit (GTO) Operations. This phase starts with observatory separation from the third stage and is completed with the firing of the AKM. After separation, the S/C controller enables a 10 minute timer to allow a safe distance before maneuvering. After timeout, the S/C controller powers the star trackers and inertial measurement units (IMUs) and initiates sun acquisition. The observatory aligns its -Y axis to the sunline to maximize the solar array power output (three of the six stowed solar array panels are illuminated with the sun on the -Y axis). RF downlink communications are maintained at a low data rate [1 kbps].

3.1.6.4 Supersynchronous Orbit Operations. This phase starts with the AKM firing and is completed after the observatory is placed into the geosynchronous earth orbit (GEO) slot. The sequence of events for the burn consists of: (i) slew to the desired burn attitude, (ii) spin the S/C to 60 rpm, (iii) begin active nutation control to dampen nutation, (iv) fire the AKM, (v) despin the observatory, and (vi) slew to initial acquisition attitude with the sun on the -Y side of the observatory. At this point the observatory is in a supersynchronous orbit with a drift of approximately 3.8° per day to the west. Over the next several days, the following activities are performed: (i) slew the observatory to operational attitude with the sun 45° from the –Z axis, (ii) eject the SRM casing, (iii) deploy the solar array/sun shield, and (iv) spin the observatory to 40 minutes per revolution. At this point the observatory can begin to be coarse trimmed for solar precession, and the high data rate mode of the RF communication system can be verified. Upon arriving at 105° west longitude, the observatory performs one burn to lower the perigee 600 km. Following sufficient time for outgassing [launch +30 days TBR] the observatory is transitioned to the science operations phase.

3.1.6.5 Science Operations. This operational activity [also referred to as Phase E or mission operations and data analysis (MO&DA)] starts with the observatory located at its GEO (note that although the observatory is in a geosynchronous orbit, it is not geostationary) and is completed after the observatory is placed into a disposal orbit. NRL's BPTF is the only ground antenna site required for science operations. The observatory checkout will last for approximately 20 days before powering on and operating the instrument. The instrument covers are left in place until operation commences. Once operation commences, the solar precession trim tabs are positioned to trim the precession rate and the trim masses are moved to align the spin axis of the observatory with the geometric axis. Once transitioned to science operations, the attitude control system on the observatory is effectively "disabled" and is in monitor only mode. In this mode, the star trackers and IMUs are active and process information for use by the instrument, but are not required to actively control the attitude of the observatory. No North-South or East-West stationkeeping maneuvers are required.

3.1.6.6 Disposal Operations. When the baseline and extended missions are complete (nominally 5 years), the observatory is placed in a disposal orbit 300 km above GEO altitude. This is performed as a thruster burn to raise perigee by 600 km. The observatory can continue collecting data after is it placed in its disposal orbit.

3.2 Performance Requirements and Physical Characteristics. This section describes the performance requirements and physical characteristics for the space segment (flight vehicle) and ground segment.

3.2.1 Performance Requirements.

3.2.1.1 Flight Vehicle. The performance characteristics of the FV **shall** be such that after separation from the ELV, the FV can achieve the orbit defined in paragraph 3.2.1.1.1 in an autonomous manner, provided the ELV meets its minimum trajectory requirements.

3.2.1.1.1 Observatory. The observatory will operate in a slightly elliptical, geosynchronous (but not geostationary) orbit with an apogee and perigee altitude constrained to GEO ±300 km. The observatory **shall** have an operational life of 2.5 years with a goal of 5 years.

The science requirements (refer to NCST-D-FM001, *Science Requirements Document*) dictate a set of observational requirements that the FAME observatory must meet (Table 3-1). Operational parameters derived from the observing parameters are listed in Table 3-2.

Table 3-1. Observing Parameters

Instrument	Focal Length	15 m
	Aperture	0.56 m along scan
		0.13 m cross scan
	CCD	Operates in Time Delay Integration (TDI) mode
		4096 (along scan) x 2048 (cross scan) pixels
		15 μm square pixels
		0.4 to 0.9 μm response range
		0.8 quantum efficiency at 600 nm wavelength
	Field of view	Two 1˚ FOV separated by 84˚ (TBR) along scan
S/C Bus	Rotation Period	40 +/- 2 minutes
	Precession Period	20 +/- 2 days
	Sun angle	45 +/- 5 deg
Catalog	Star Positions	0.5 μrad

Table 3-2. Derived Parameters

CCD Integration Time	1.56 sec
CCD Well Capacity	greater than 100,000 electrons
Plate scale	1 μrad/pixel
	206 mas/pixel
Rotation rate	2.62 +/- 0.13 mrad/sec
Point Spread Function	Sufficient to allow centroiding to 0.0028 μrad along scan

3.2.1.1.1.1 S/C Bus Characteristics and Performance Requirements.

3.2.1.1.1.1.1 S/C Bus Characteristics. The spacecraft bus consists of the following subsystems and the necessary MAGE and EAGE:

a. Attitude Determination and Control Subsystem (ADCS) (paragraph 3.7.1.1.1.1)

b. Command, Telemetry, and Data Handling (CT&DH) Subsystem (paragraph 3.7.1.1.1.2)

c. Electrical Power Subsystem (EPS) (paragraph 3.7.1.1.1.4)

d. Flight Software (FSW) (paragraph 3.7.1.1.1.5)

e. Ground Software (GSW) (paragraph 3.7.1.1.1.6)

f. Harness (paragraph 3.7.1.1.1.7)

g. Mechanism Subsystem (paragraph 3.7.1.1.1.9)

h. Ordnance Control Subsystem (OCS) (paragraph 3.7.1.1.1.4.1)

i. Radio Frequency (RF) Subsystem (paragraph 3.7.1.1.1.10)

j. Reaction Control Subsystem (RCS) (paragraph 3.7.1.1.1.11)

k. Structures Subsystem (paragraph 3.7.1.1.1.12)

l. Thermal Control Subsystem (TCS) (paragraph 3.7.1.1.1.13)

3.2.1.1.1.1.2 S/C Bus Performance Requirements. The S/C bus **shall** be capable of complete checkout and tests prior to launch. The primary requirements of the S/C bus are to:

a. Place the P/L in the proper orbit. The S/C bus **shall** provide the necessary guidance, propulsion, and attitude control capabilities required to transition the FV from the ELV separation plane to the final mission orbit defined in paragraph 3.2.1.1.1. ELV discrete telemetry, in conjunction with an independently derived FV discrete, **shall** be used to develop redundant FV-ELV separation signals.

b. Provide a long term stable platform for the P/L. To provide a stable platform for P/L observations, no actively moving components will be used. Solar pressure will be used for precession of the observatory spin axis around the sun vector. The S/C bus thermal stability will be maintained with constant power and temperatures to eliminate structural expansion or contraction. Passive damping will be employed to maintain a low level of jitter.

c. The S/C bus **shall** use vectors or orbital element sets representing the orbit of the observatory at periodic intervals for instrument and S/C bus pointing accuracy and for location correlation of the mission data. The data **shall** be uplinked from the ground segment at periodic intervals defined by program needs.

d. Collect, buffer, format for downlink, and transmit the resulting science data to the Ground Data System (GDS)

e. Shield the instrument from the sun

f. Provide power for the instrument and S/C bus subsystems

g. Provide communications between the instrument and the S/C bus

h. Receive commands and transmit telemetry. The command uplink and status telemetry downlink **shall** be fully compatible with NASA Spaceflight Tracking Data Network (STDN) specifications as described in paragraph 3.7.2. No Communications Security (COMSEC) encryption or decryption **shall** be required. The telecommunications system **shall** support range and range rate tracking. The S/C bus attitude and state of health (SOH) housekeeping and status telemetry (H&ST) will be continually monitored for nominal conditions via the GDS. The observatory **shall** use NASA's existing S-Band frequency allocations. The NRL **shall** determine the specific frequency, together with acceptable alternate frequencies in accordance with the guidelines of NASA Handbook 2570.6A. The NRL **shall** submit NASA Form 566 for assignment of frequency allocations.

i. Provide mechanical support for the instrument and S/C bus subsystems

j. Provide an interface between the S/C bus and the interstage and AKM. The S/C bus will be designed with a central thrust tube and structure to accommodate an AKM and a hydrazine propulsion system.

k. The S/C bus and ELV coordinate systems and the relations between them will be defined in the FAME S/C Design Specification (NCST-S-FM001) and the FAME S/C Bus to ELV ICD (NCST-ICD-FM002).

3.2.1.1.1.2 Instrument Characteristics and Performance Requirements.

3.2.1.1.1.2.1 Instrument Characteristics.

3.2.1.1.1.2.1.1 Instrument Optical Subsystem. The star images from the two FOVs are projected onto a single Focal Plane Assembly (FPA) by the optical system. The optical system consists of a compound mirror assembly, a telescope consisting of three powered optics, and a series of fold flats.

3.2.1.1.1.2.1.2 Instrument Focal Plane Assembly. The FPA includes a housing, CCD subassemblies, optical filters, the FPA window, CCD wiring, preamplifiers, electronic filters, clock terminations, associated electronics, and a thermal link to the radiator. The FPA provides the support structure for the CCD subassemblies, maintains CCD positional alignment, and serves to thermally isolate the CCDs from the rest of the instrument. The FPA is passively cooled to operating temperature through a thermal link assembly tied directly to the instrument radiator panel.

3.2.1.1.1.2.1.3 Instrument Structure. The instrument structure:

a. Serves as the instrument backbone. The structure maintains the alignment of the optical elements and FPA.

b. Provides a three point mechanical interface to the S/C bus.

c. Consists of a truss, baffles with aperture doors, and light panels.

3.2.1.1.1.2.1.4 Instrument Thermal Control. The instrument thermal control system (TCS):

a. Maintains the individual optics and the structure at a stable temperature.

b. Maintains the CCD at a proper operating temperature.

c. Consists of a CCD radiator panel, thermal blankets, and heaters.

3.2.1.1.1.2.1.5 Instrument Electronics, Software, and Data Processing. The instrument electronic, software, and data processing subsystem:

a. Interprets the on-board input star catalog and determine the locations of the stars on the CCD

a. Provides the CCD with the proper clocking signals to operate the CCDs in TDI mode

b. Windows the CCD data

c. Provides analog-to-digital converters (ADCs) for processing CCD data

d. Provides memory storage for the onboard input star catalog

e. Determines the instrument's fine attitude from the coarse measurements supplied by the S/C bus.

f. Determines the instrument attitude and rotation rate

g. Provides housekeeping monitors

h. Formats the science data stream

i. Consists of a camera control assembly, data processor assembly, analog processor assembly, and wiring harness.

3.2.1.2 Ground Segment.

3.2.1.2.1 Ground Segment Performance Characteristics.

a. The observatory ground segment will use the NRL Blossom Point Satellite Tracking Facility (BPTF) [augmented by NASA's Deep Space Network (DSN) for early on-orbit operations], a Mission Operations Center (MOC) located at BPTF, and a Science Operations Center (SOC) located at USNO.

b. The MOC will be responsible for day-to-day flight operations. All nominal communications with the observatory will be via the MOC in all mission phases. During the science operations phase of the mission, observatory servicing, and tasking nominally occur during a single daily upload from the MOC. This upload includes immediate and stored S/C bus servicing routines and scripted P/L tasking. These scripts are developed at the SOC, sent electronically to the MOC, verified, and then stored until the transmission time specified by the SOC.

c. The SOC will be responsible for P/L operations. In addition to operating the P/L, the SOC collects and analyzes observatory science data. The SOC will analyze science data in near realtime to monitor image detection, image quality, and satellite attitude using a First Look and Troubleshooting Pipeline. The raw science data, along with various intermediate products, are archived, reduced, and analyzed to produce mission science deliverables that will include a catalog of the astrometric and photometric parameters for each of the 40 million stars observed during the mission.

3.2.1.2.2 Ground Segment Performance Requirements.

3.2.1.2.2.1 Mission Operations Center. After FV separation from the ELV, the MOC will receive FV or observatory HS&T continuously while the observatory is in view. HS&T will be archived at the MOC where real-time HS&T data monitoring and SOH assessment will be performed. The MOC's Flight Operations Team (FOT) will perform observatory trending and analysis throughout the mission lifetime. All mission activities will be planned, scheduled, and executed by the FOT at MOC. The MOC:

a. **Shall** develop a GDS architecture capable of supporting all anticipated flight operations activities.

b. **Shall** plan and implement all on-orbit flight operations activities, including:

(1) Managing uplink and downlink data flows;

(2) Receiving, displaying, and archiving observatory downlink telemetry,

(3) Collecting and processing range and range-rate data,

(4) Providing orbit determination (OD) capability;

(5) Generating verified FV and observatory flight software (FSW) loads and patches, commands, and command sequences;

(6) Processing telemetry data and displaying housekeeping and attitude information locally to assess the health and status of the FV or observatory;

(7) Electronically transferring status reports to the SOC on a weekly basis, or as required; and

(8) Receiving verified instrument payload commands from the SOC, formatting these commands into valid command sequences, and uplinking these sequences to the observatory.

3.2.1.2.2.2 NASA's Deep Space Network Support Complexes. After FV separation from the ELV, DSN support complexes at Madrid, Spain and Canberra, Australia will augment MOC support when the FV is not in view of BPTF. Telemetry collections and commanding with DSN will be on a "bent-pipe" basis, with the MOC functioning as the command initiator and telemetry collector. After the launch phase, DSN support will be on an "as-requested" basis. DSN stations at Madrid and/or Goldstone, CA will exercise their telemetry collection and command capabilities on a weekly basis to allow their usage if a space or ground emergency occurs.

3.2.1.2.3 FAME Science Operations Center. The SOC (located at the USNO) will receive real-time data from the MOC, including all data streams relevant for instrument P/L operations and science data analysis. During normal working hours, the SOC will monitor the instrument P/L H&ST. Anomalies will be identified and resolved in cooperation with the MOC. The SOC will archive the data stream received from the MOC along with critical intermediate data products. The SOC will operates a First Look and Troubleshooting Pipeline to monitor and trend instrument star detection, image quality, and S/C attitude. Anomalies in the output of the First Look and Troubleshooting Pipeline or anomalous changes in trend slopes will be investigated and resolved in cooperation with the MOC. The SOC will operate the instrument P/L, will monitor nominal instrument operation and H&ST, and plan instrument mission activities. The SOC develops instrument tasking scripts that are sent electronically to the MOC, verified, then stored for transmission to the S/C. The SOC operates an astrometric/photometric data reduction pipeline that will use raw observational data from the S/C to produce the mission science deliverables; which include the FAME catalog of the astrometric and photometric parameters for each of the 40 million stars observed during the mission.

3.2.2 Physical Characteristics. The following subparagraphs describe the general requirements for the physical characteristics that are applicable to only the observatory space segment.

3.2.2.1 Mass Properties.

a. The mass of the FV (i.e., S/C bus, interstage, AKM, and instrument) **shall** not exceed the maximum throw weight of the ELV.

b. Mass properties **shall** be defined, reported, and controlled to preserve the performance margins specified in the S/C bus to ELV ICD (NCST-ICD-FM002).

3.2.2.2 Dimensions and Envelope.

a. The observatory launch configuration **shall** be compatible with the ELV fairing.

b. The dimensional envelope constraints **shall** consider all combinations of dynamic and thermal environments encountered in all operational phases, including factory assembly, system test, transportation, launch, ascent, and deployment.

c. Dimensional envelope constraints on the FV relative to the ELV **shall** be defined in the FAME S/C Bus to ELV ICD (NCST-ICD-FM002).

d. Other dimensional and envelope constraints **shall** consider the placement of the P/L and any other S/C bus viewing sensors to preclude operational interference among any flight elements of the space segment.

3.2.2.3 Coordinate System. Figure 3-4 shows the observatory coordinate system. This coordinate system is right handed system defined such that +z is parallel to the launch vehicle axis and y is parallel the optical axis of the figured mirrors with +y pointing away from the compound mirror.

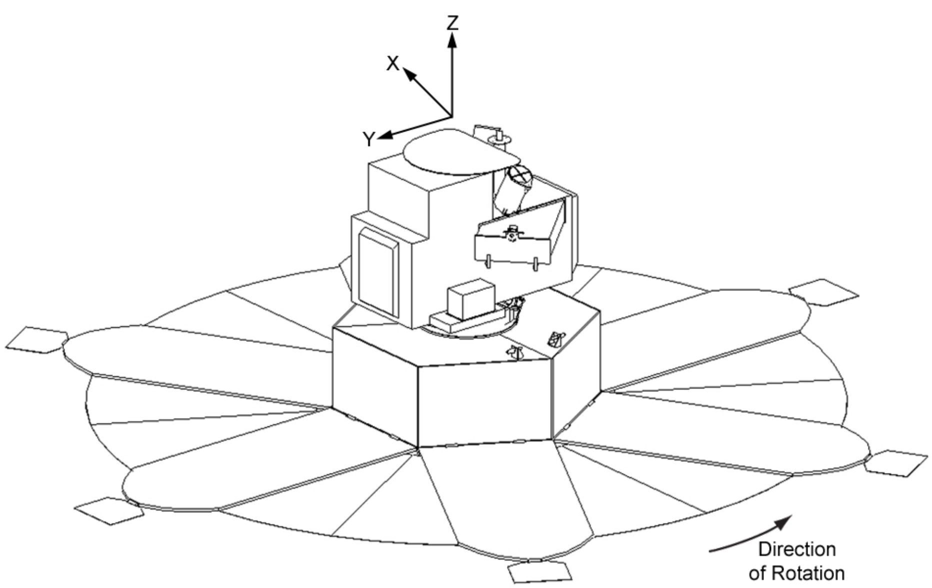

Figure 3-4. FAME Observatory Coordinate System

3.2.3 System Quality Factors.

a. The Reliability and Quality Assurance (R&QA) program **shall** be defined in NCST-D-FM005, FAME Product Assurance Plan. In general, non redundant, single-string designs may be used to contain costs and single point failure (SPF) modes will be allowable (see paragraph 3.2.3.4). To mitigate the risk associated with single-string designs, and to enhance the operable lifetime, EEE parts selected from GSFC's 311-INST-001 with a quality level no lower than Level 2 will be used (see paragraphs 3.3.1.1 and 3.3.1.2).

b. Extra consideration **shall** be given to personnel or launch vehicle safety issues that could relate to SPF modes. New technology hardware will be flight qualified through tailored tests and analyses. Reviews of heritage hardware pedigrees will be performed to determine the applicability of design and test history relative to the FAME mission requirements. The following subparagraphs describe the general requirements for the system quality factors that are applicable to only the observatory space segment.

3.2.3.1 Failure Modes and Effects Analysis (FMEA). As part of the design process, an FMEA (NCST-D-FM011) **shall** be performed on critical FV interfaces where a failure can propagate to loss of the mission.

3.2.3.2 Electrical Stress Analysis. As part of the design process, an electrical stress analysis **shall** be performed on the observatory using the derating criteria guidelines contained in Section 3.3.1.3.

3.2.3.3 Reliability.

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

b. Reliability calculations **shall** not include those factors applicable to launch, ascent, and FV or observatory separation operations.

c. The reliability allocations **shall** ensure that the overall science mission requirements are met under all reasonable conditions for storage, transportation, testing, and operations.

d. As a goal, the S/C bus design **shall** be such that a failure in one component does not propagate to other components.

e. As a goal, the S/C bus **shall**, when practical, be capable of detecting malfunctions and automatically initiating protective measures to avoid loss of the mission.

3.2.3.4 Single Point Failures.

a. As part of the design process, mission-critical SPF **shall** be identified and documented in the FMEA (paragraph 3.2.3.1).

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

c. Provisions **shall** be made, when practical, to enable monitoring of SPF (as described in paragraph 3.2.3.1) that could give rise to critical or catastrophic hazards, or to mission loss of the telemetry system. SPFs will be identified on the Critical Items List.

3.2.3.5 Redundancy.

a. As part of the design process, redundancy options **shall** be identified, and adequate redundancy **shall** be provided, where practical, to eliminate SPF and to ensure the mission achieves its 2.5 year mission life requirement.

b. In the design of redundancy, or the elimination of potential (i.e., low-risk) SPF, care **shall** be taken not to reduce the overall space segment reliability due to added complexity caused by connectors, wiring and harnesses, components, and operational issues.

3.2.3.6 Worst Case Analysis.

a. 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 observatory.

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

c. 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 the tailored guidelines of SSD-D-IM007 or IEEE-STD-1332-1998, as well as automated tools, logic simulations, or statistical methods is encouraged.

3.2.4 Systems Effectiveness Models.

a. *Structural Model*: A design analysis or an analytical model (*Design Loads Analysis Plan*, NCST-D-FM017) **shall** be developed that correlates the structural modes to within 5 percent of the experimental results. The analytical model, if used, should be written in NASTRAN or equivalent.

b. *Thermal Model:* Thermal models (SINDA85, TRASYS, or equivalent) **shall** be verified by test at the S/C bus or observatory level.

3.2.5 Environmental Conditions.

a. The space segment and all of its elements **shall** be designed to operate within specification limits during and after exposure, as applicable, to all creditable combinations of operating and non-operating environments.

b. The space segment elements **shall** be protected during ground handling and transportation so that the environmental conditions do not exceed flight or orbital conditions.

c. These constraints **shall** not be interpreted as precluding environmental testing of the space segment elements.

The following subparagraphs describe the general requirements for the environmental conditions that are applicable to only the observatory space segment.

3.2.5.1 Non-Operating Environment. The observatory, with the exception of the batteries and ordnance, **shall** meet the requirements of this document without refurbishment or adjustment after exposure to any combination of the environments specified herein for Integration and Test (I&T) at NRL (paragraph 3.2.5.1.1), ground handling and transportation (paragraph 3.2.5.1.2), and prelaunch (paragraph 3.2.5.1.3).

3.2.5.1.1 NRL Integration and Test Facility Environment. The observatory, except for batteries and ordnance, **shall** meet the requirements of this document without refurbishment or adjustment after exposure to any combination of the I&T environments listed below:

a. *Ambient Air Temperature:* Maintained at a level typical of NRL's Building A-59 Payload Processing Facility (PPF).

b. *Ambient Pressure*: Naturally occurring at sea level and at 1500 feet.

c. *Humidity:* Maintained at a level typical of the NRL PPF. Appropriate measures will be implemented to prevent the formation of condensation on the observatory, test equipment, or protective covers.

d. *Acceleration, Vibration, Shock, and Loads:* Not applicable.

e. *Cleanliness:* Flight hardware maintained in accordance with the requirements of NCST-D-FM007, *Contamination Control Plan*.

3.2.5.1.2 Ground Handling and Transportation. The observatory **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:

a. *Ambient Air Temperature:* External environment is uncontrolled and will range from -10˚C to +40˚C.

b. *Ambient Pressure*: Naturally occurring at sea level to 30,000 feet.

c. *Humidity:* Internal shipping container environment controlled to prevent condensation of moisture or frost on flight hardware.

d. *Acceleration, Vibration, Shock, and Loads:* Observatory **shall** not be exposed to environments greater than those experienced during launch and ascent.

e. *Cleanliness:* Protective container or packaging to maintain flight hardware at the cleanliness level specified in NCST-D-FM007, *Contamination Control Plan*.

3.2.5.1.3 Prelaunch. The observatory **shall** meet the requirements of this document without refurbishment or adjustment after exposure to any combination of prelaunch environments (environments that occur from arrival at the ELV launch site to launch) listed below:

a. *Ambient Air Temperature:* Maintained from 7.2˚C to 33˚C.

b. *Ambient Pressure*: Naturally occurring at sea level and at 1500 feet.

c. *Humidity:* Maintained between [30% and 90%]. Appropriate measures will be implemented to prevent the formation of condensation on the observatory, test equipment, or protective covers.

d. *Acceleration, Vibration, Shock, and Loads:* Observatory **shall** not be exposed to environments greater than those experienced during launch and ascent.

e. *Cleanliness:* Assembly, test, and preparation area controlled to meet the environment specified in NCST-D-FM007, *Contamination Control Plan*.

3.2.5.2 Operating Environment. The observatory **shall** be designed to perform as specified for 2.5 years (requirement) or 5 years (goal) after exposure to the environments specified herein for launch and ascent (paragraph 3.2.5.2.1) and on-orbit operations (paragraph 3.2.5.2.2).

3.2.5.2.1 Launch and Ascent. The launch and ascent phase covers those environments that occur between terminal countdown and separation from the third stage.

a. The observatory **shall** meet the requirements of this document without refurbishment or adjustment after exposure to the thermal, pressure, acceleration and loads, random and acoustic vibration, and shock specified in NCST-D-FM017, *FAME Design Loads Analysis Plan*.

b. The thermal, pressure, acceleration and loads, random and acoustic vibration, and shock specified in NCST-D-FM017, *FAME Design Loads Analysis Plan,* **shall** be consistent with the requirements defined in NCST-ICD-FM002, *FAME S/C Bus to ELV ICD*.

3.2.5.2.2 Orbital Operations. The orbital operations phase covers those environments that occur when the observatory reaches geosynchronous altitudes. The observatory **shall** meet the requirements of this document during exposure to any combination of the following environments:

3.2.5.2.2.1 Natural Thermal Radiation. The natural thermal radiation environmental constants are shown in Table 3-3. Because the observatory will be operating in a geosynchronous orbit, earth albedo and infrared inputs will be negligible. The S/C bus and P/L will be the subject of a sensitivity study to gauge the effects of small values for these constants. The observatory **shall** meet the requirements of this document without refurbishment or adjustment during exposure to any combination of the environments listed in Table 3-3.

Table 3-3. Natural Thermal Radiation Information

Environmental Parameter	Units	Design
Solar Radiation	BTU/hr ft^2	415 to 444
Earth Albedo	Percent of solar radiation	0
Earth Infrared	BTU/hr ft^2	0
Space Sink Temperature	˚K	0

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

3.2.5.2.2.3 Particle Radiation. The observatory will be subjected to galactic cosmic radiation, geomagnetically trapped particle radiation, and solar particle event (SPE) radiation (Table 3-4). 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 3-5.

Table 3-4. 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.

3.2.5.2.2.3.1 Total Ionizing Dose.

a. 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 Figure 3-5 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.

b. 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.

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

a. The galactic cosmic ray design environment for the nominal case of 150 mils Al shielding during solar minimum conditions is shown in Figure 3-6.

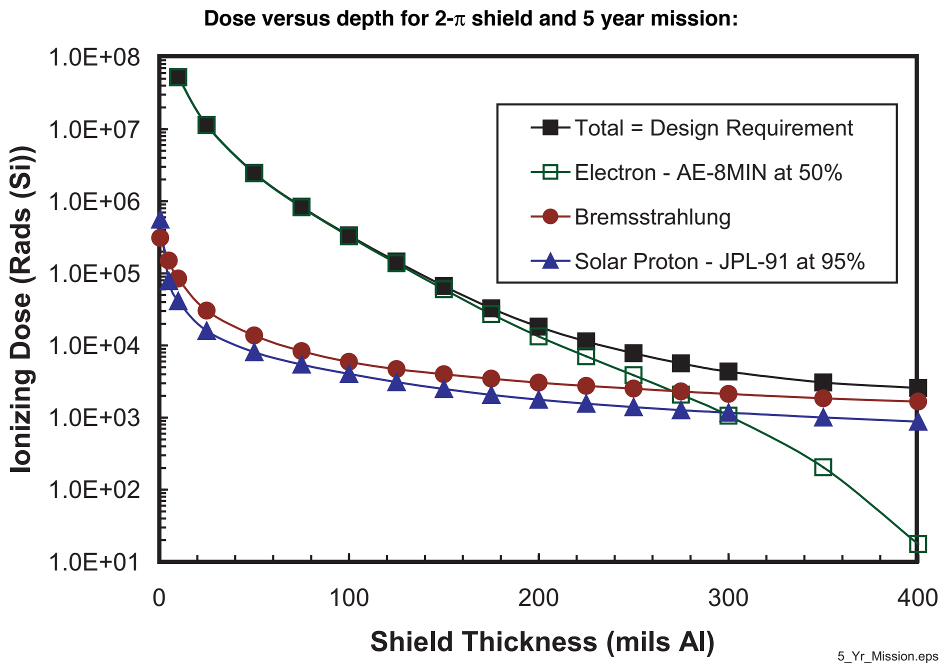

Figure 3-5. Observatory Radiation Environment

b. 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.

c. For SEE analyses, the design worst-case particle flux spectrum (corresponding to the October 89 SPE) is provided in Figure 3-7. 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.

3.2.5.2.2.3.2.1 Single Event Induced Destructive Failure.

a. 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.

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

3.2.5.2.2.3.2.2 Single Event Induced Non-Destructive Failure.

a. 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.

b. 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).

3.2.5.2.2.3.2.3 Single Event Induced Soft Errors.

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

b. 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).

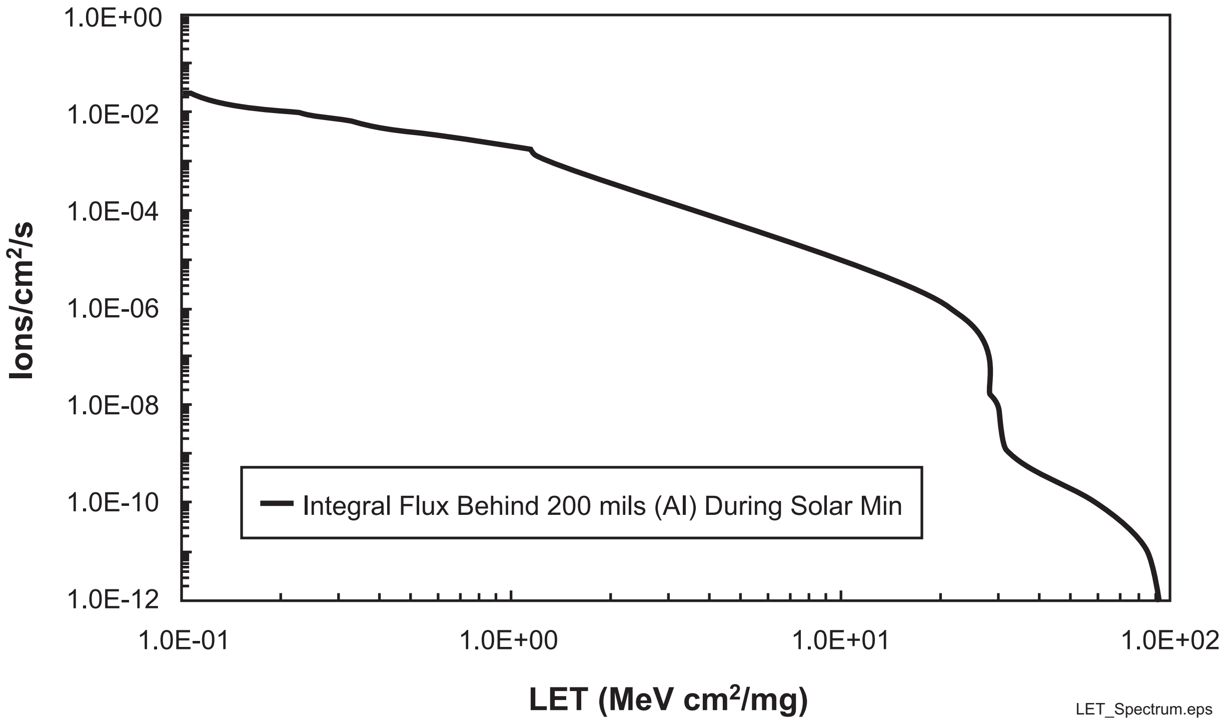

Figure 3-6. FAME Cosmic Ray LET Spectrum
Calculated during solar minimum (normal) conditions with 200 mils Al hemispherical shielding and 0 GV geomagnetic cutoff.

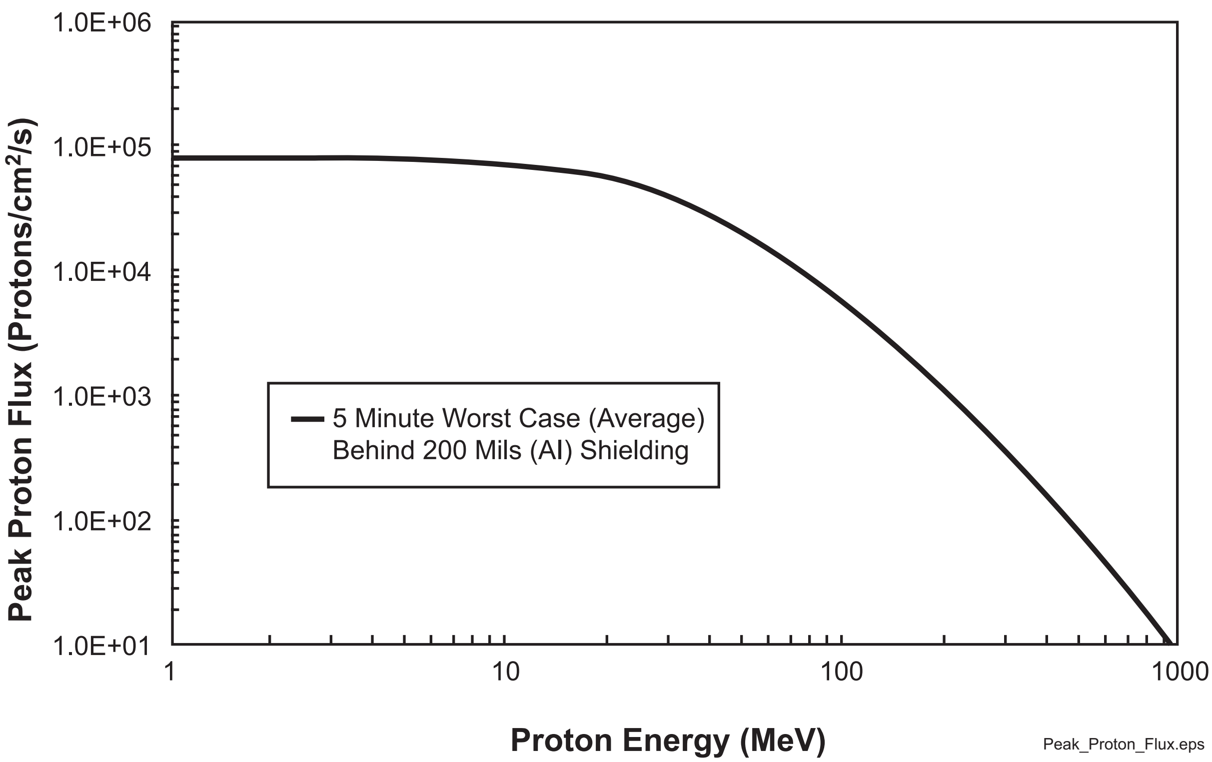

Figure 3-7. Integral Solar Particle Peak Proton Flux

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 NCST-D-FM005, *FAME Product Assurance Plan*, that implements the guidelines contained in GSFC-410-MIDEX-001, paragraph 5.1, *Parts*, and paragraph 5.2, *Materials and Processes*.

a. 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.

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

c. 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*.

d. 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 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.

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

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

3.3.1.2 EEE Parts Procurement, Processing, and Screening. The following guidelines **shall** be used for establishment of the FAME parts program.

a. 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.

b. Specific FAME program parts screening requirements are as follows:

(1) 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.

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

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

(4) 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.

(5) 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.

(6) 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.

3.3.1.3 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 SSD-D-IM007 (as tailored for the FAME program), MIL-STD-975M, MIL-HDBK-1547A.

3.3.1.4 Electrostatic Discharge Sensitive EEE Parts.

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

b. ESD protection **shall** be in accordance with approved processes and procedures that implement NASA-STD-8739.3, MIL-STD-1686, or EIA-625 guidelines.

3.3.1.5 Materials.

3.3.1.5.1 Outgassing.

a. 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.

b. Any materials that fail to meet these criteria **shall** be identified to the FAME PMO.

3.3.1.5.2 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.

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

b. 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.

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

d. Pressurized systems **shall** meet the requirements of MIL-STD-1522 and EWRR 127-1.

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

3.3.1.5.4 Finishes.

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

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

3.3.1.5.5 Toxic Products and Formulations. Toxic products and formulations **shall** meet the applicable OSHA and launch site safety requirements.

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

3.3.1.5.7 Polymer Materials. Uralane **shall** be used for conformal coating applications.

3.3.1.6 Processes.

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

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

b. Soldering of electrical connections **shall** be in accordance with ANSI/J-STD-001 (High Reliability Class) and the applicable associated standards ANSI-J-STD-002 through -006 or to process specifications that implement NASA-STD-8739.3 and NASA-STD-8739.4 guidelines.

c. Crimping of electrical connections **shall** be in accordance with process specifications that implement NASA-STD-8739.4 guidelines.

d. Conformal coating and staking of printed wiring boards and electronic assemblies **shall** be in accordance with process specifications that implement NASA-STD-8739.1 guidelines.

e. 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.

3.3.1.6.2 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.

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

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

(1) 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.

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

(3) Traceability records **shall** be as shown in Table 3-5.

Table 3-5. 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

c. 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.

d. 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).

3.3.1.6.3 Failure Reporting and Corrective Action System.

a. A closed loop failure reporting and corrective action system (FRACAS) for reporting, analysis, and corrective action **shall** be in effect for failures occurring during the acceptance testing phases and continuing until integration with the ELV. After observatory integration with the ELV, a problem and corrective action (PRACA) system will be maintained according the requirements identified in the FAME S/C Bus to ELV ICD (NCST-ICD-FM002).

b. The FRACAS **shall** determine whether failures are caused by design deficiencies, human error, defective parts, infant mortality, test equipment, environmental exposure, or software.

3.3.2 Electromagnetic Environment. The observatory **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 NCST-D-FM018, *FAME EMI/EMC Control Plan*.

3.3.3 Corona Suppression. The observatory **shall** be designed to minimize the occurrence of corona discharge in all normal operating environments.

3.3.4 Nameplate and Product Marking. Observatory components that are interchangeable **shall** be identified by part number and serial number or lot number.

3.3.5 Workmanship.

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

b. 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.

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

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

c. The observatory **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 NRL and the ELV launch site.

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

e. 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 Human Performance and Human Engineering. The design of the space segment and the ground segment **shall** include consideration of human performance and human engineering requirements. Specific attention **shall** be given to human-machine interfaces (HMIs) within established design, engineering, manufacturing, and operations practices.

3.3.8 System Security.

a. The space segment **shall** provide protection for uplinked commands to prevent unauthorized third party control of the on-orbit observatory.

b. COMSEC via encrypted uplinks or downlinks **shall** not be required.

3.3.9 Computer Resources. Computer resources include all computer programs and associated computational equipment included within the space segment. Computational equipment includes both the equipment that executes symbolically expressed instructions and the associated peripheral devices.

a. The system design **shall** provide positive memory and processing margins (100% margin at CDR). Computer resources in the space segment are grouped and identified as:

   (1) Those which functionally support operations;

   (2) Those used for computer program maintenance;

   (3) Those embedded in test equipment; and

   (4) Those included in other functional areas such as simulators.

b. Specific requirements for these areas of computer resources **shall** be in accordance with NCST-SDP-FM001, *FAME Flight Software Development Plan*, and NCST-SDP-FM002, *FAME Ground Software Development Plan*, which implement the guidelines of NASA-STD-2100-91 and GFSC-410-MIDEX-002, paragraph 5.4.

3.3.10 Standards of Manufacture.

3.3.10.1 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.

a. 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.

b. 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.

c. 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.

d. When approved by the FAME PMO, these flowcharts and referenced specifications, procedures, drawings, and supporting documentation **shall** become the manufacturing process control baseline and **shall** be retained for reference.

e. Any changes to the baseline processes used, or the baseline documents used, when approved by the FAME PMO, **shall** be recorded following the production of the first item.

3.3.10.2 Production Lots.

a. 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.

b. 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.

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

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

3.3.10.3 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 NCST-D-FM007, *FAME Contamination Control Plan*.

3.3.10.4 Connectors.

a. Connector keying or equivalent means **shall** be used to prevent mismating.

b. 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.

3.3.10.5 Positive Locking Devices.

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

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

3.4 Documentation. Documentation **shall** be consistent with established operation practices except as tailored to meet specific observatory requirements.

3.4.1 Specifications. Design specifications related to the observatory will be prepared in accordance with the guidelines of MIL-STD-961, *Specification Practices*, NCST-SDP-FM001, *FAME Flight Software Development Plan*, or NCST-SDP-FM002, *FAME Ground Software Development Plan*, as applicable. 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.

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

b. This documentation **shall** also be adequate to allow the rapid incorporation of changes and modifications that have been approved by the FAME PMO.

3.4.3 Software Support Documentation. All software support documentation **shall** be prepared in accordance with the guidelines of NCST-SDP-FM001, *FAME Flight Software Development Plan* and NCST-SDP-FM002, *FAME Ground Software Development Plan*.

3.4.4 Test Plans and Procedures. All test plans and procedures will be documented so that testing of the system can be accomplished by skilled engineering personnel. Software test plans, descriptions, and procedures **shall** be prepared in accordance with the guidelines set forth in NCST-SDP-FM001, *FAME Flight Software Development Plan* and NCST-SDP-FM002, *FAME Ground Software Development Plan*.

3.5 Logistics. Logistics planning will include identification and procurement of long-lead and critical spares, repair parts, support facilities and equipment, training of personnel, and maintenance support at the test and launch sites, consistent with the one-time use of the system. No scheduled or preventive maintenance will be required to meet the performance and reliability requirements specified herein.

3.6 Personnel and Training. A concise and streamlined training program, emphasizing “on-the-job” training, will be implemented to train the appropriate personnel for the conduct of tests, processing, and on-orbit operations defined herein.

3.7 Major Component Characteristics. The FAME mission comprises two system segments, the space segment and the ground segment. The space segment consists of the FV and associated GSE. The ground segment consists of all ground command, communications, control, data distribution, and data analysis facilities and concepts.

3.7.1 FAME Flight Vehicle. The FAME FV shall consist of the FAME observatory (see paragraph 3.7.1.1) and the interstage assembly (see paragraph 3.7.1.1.2).

3.7.1.1 FAME Observatory. The FAME observatory shall consist of the S/C bus (see paragraph 3.7.1.1.1) and the instrument P/L (see paragraph 3.7.1.1.2).

3.7.1.1.1 FAME S/C Bus. The S/C bus **shall** consist of the following major subsystems identified in the paragraphs below.

3.7.1.1.1.1 Attitude Determination and Control Subsystem. The ADCS acquires a safe orientation after initial separation, orients the spin axis for perigee raising, and maintains pointing during AKM firing. Subsequently, it re-orients the S/C for all orbit trim and stationkeeping maneuvers, as well as any safe hold operations. The ADCS principal function is to generate the critical scan motion required by the FAME instrument to perform its star mapping mission.

3.7.1.1.1.1.1 Spin Period. The ADCS subsystem **shall** provide a nominal spin period of 40 minutes +/-4 minutes during data collection for the life of the mission.

3.7.1.1.1.1.2 Sun Angle. The ADCS subsystem **shall** provide a nominal sun angle of 45 degrees +/- 5 degrees during data collection for the life of the mission, as measured from the -Z direction of the spin axis.

3.7.1.1.1.1.3 Precession Period. The ADCS subsystem **shall** provide a nominal precession period of 20 days +/-2 days during data collection for the life of the mission.

3.7.1.1.1.2 Command, Telemetry & Data Handling Subsystem. The CT&DH subsystem will use the FAME Spacecraft Controller (FSC) to provide the following capabilities:

a. **Shall** decode, authenticate and process unencrypted CCSDS commands received via the uplink
b. **Shall** execute critical commands without CPU interaction
c. **Shall** execute stored commands
d. **Shall** distribute commands to all FV and observatory subsystems
e. **Shall** transfer specific uplink data to instrument for control and reprogramming
f. **Shall** communicate with FV and observatory subsystems
g. **Shall** collect SOH telemetry from all FV and observatory subsystems
h. **Shall** collect, store, and buffer instrument payload science data generated at a maximum data rate of 4 Mbps for an average data rate of 320 kbps while using a maximum memory storage allocation of 4 Gigabits
i. **Shall** store instrument payload science and telemetry data up to the maximum allocated storage capability during scheduled or unscheduled downlink outages
j. **Shall** provide for downlink telemetry capability of 409.6 kbps [TBR] of science and telemetry data
k. **Shall** provide error control coding and data interleaving to the downlink telemetry data stream
l. **Shall** maintain and distribute S/C bus time to and observatory subsystems
m. **Shall** manage FV and observatory attitude for successful mission orbit insertion, stabilization, and de-orbit
n. **Shall** provide timers to achieve "safe distance" between third stage and FV prior to initiation of GTO insertion maneuvers
o. **Shall** provide for an interface to Electrical Aerospace Ground Equipment (EAGE) for initial integration
p. **Shall** support the T-minus zero (T-0) interface to the ELV

3.7.1.1.1.3 Electrical Aerospace Ground Equipment. The FAME EAGE:

a. **Shall** protect flight hardware during test

b. **Shall** simulate 2 kbps CCSDS uplink to S/C bus

c. **Shall** accept rates from 1 kbps to 1 Mbps downlink from S/C bus

d. **Shall** provide 30 +/- 6 DC power to S/C bus for system level testing and pre-launch activities

e. **Shall** simulate/provide 600 W at 30 VDC solar array/battery power

f. **Shall** provide S/C bus critical bus/component protection from EAGE overvoltage and/or overcurrent anomalies

3.7.1.1.1.4 Electrical Power Subsystem (EPS). The FAME EPS:

a. Shall supply electrical energy to all spacecraft subsystems and the instrument during all mission phases

b. Shall not be damaged by operational, electrical, and ACS faults

c. Shall be fully recoverable from operational, electrical, and ACS faults

d. Shall minimize, by design, disturbance torques to the Observatory attitude

e. Shall provide EPS health and status to the spacecraft CD&DH subsystem

f. Shall provide control of all spacecraft motors and heaters

g. Shall provide electrical energy to activate all ordnance devices in accordance with the EWRR 127-1

3.7.1.1.1.4.1 Ordnance Control Subsystem. The OCS:

a. **Shall** provide the necessary switching and control logic to enable, arm, and execute S/C bus ordnance functions in accordance with the requirements of MIL-STD-1576

b. **Shall** provide the following functions:

   (1) S/C bus and AKM separation

   (2) AKM inhibit, arm, and fire

   (3) Solar panel deployment

c. The OCS electronic circuitry **shall** be configured to provide the necessary interrupt and fault tolerance required by EWRR 127-1.

3.7.1.1.1.5 Flight Software. The FAME FSW:

a. **Shall** be developed in accordance with NCST-SDP-FM001, *FAME Flight Software Development Plan*

b. New flight software:

   (1) **Shall** conform to the standards and requirements specified in NCST-SDP-FM001

   (2) **Shall** conform to the operational standards and requirements specified in NCST-SRS-FM001, *FAME Flight Software Requirements Specification*

   (3) **Shall** provide the data processing necessary to implement such items as flight operations control, fault isolation, and redundancy management

c. **Shall** provide the capability to upload and change on-orbit FSW

d. **Shall** provide the capability to dump the FSC processor memory

e. **Shall** provide the capability to detect and isolate faults, report status, and provide sufficient engineering data to the telemetry system to verify subsystem operations

f. **Shall** provide periodic self-test of the computational elements

g. **Shall** be designated as a Mission Critical Computing Resource (MCCR)

3.7.1.1.1.6 Ground Software. The FAME S/C bus ground software:

a. **Shall** provide command, control, and telemetry support for all FAME I&T configurations

b. **Shall** provide command, control, and telemetry support for all FAME operational configurations

c. **Shall** provide compatibility with NRL's Blossom Point (BP) ground station system architecture

d. **Shall** control a dedicated 11.3-m antenna system at BP

e. **Shall** provide automated control of ground configurations via an extendible scripting language

f. **Shall** support telemetry acquisition and processing for a continuous CCSDS packetized data stream at a the FAME data rates

g. **Shall** forward science data packets and instrument SOH packets to the SOC in real-time

h. **Shall** support monitoring of the on-orbit FAME observatory, including systems status analysis, limit checking, out-of-limits reporting and trending analysis

i. **Shall** provide telemetry archive and playback for both science data and SOH data

j. **Shall** support command uplink and verification per CCSDS COP-1 protocols

k. **Shall** support three command modes:

(1) Real-time

(2) Ground preplanned

(3) Onboard scheduling based on uplinked command loads

l. **Shall** support verification of command execution, analysis of results, investigation of anomalies, and response to off-nominal situations

m. **Shall** support initiation of safing measures whenever it is determined that a critical event seriously jeopardizes the mission if it were to continue to operate beyond defined and acceptable operating limits

n. **Shall** support calculation of S/C velocity knowledge, range, and range rate data to 1 cm/second

3.7.1.1.1.7 Harness Subsystem. The FAME harness subsystem:

a. Shall provide signal and power connectivity between all spacecraft subsystems

b. Shall provide signal and power connectivity between the instrument and the spacecraft

c. Shall provide signal and power connectivity between the observatory and the launch vehicle

3.7.1.1.1.8 Mechanical Aerospace Ground Equipment (MAGE). FAME MAGE provides all necessary fixtures and adapters for safe handling, testing, and transportation of FAME flight hardware during all phases of assembly, integration, test, transportation, and field operations. FAME MAGE:

a. **Shall** maintain FAME flight hardware cleanliness levels as specified in NCST-D-FM007, *FAME Contamination Control Plan*

b. **Shall** protect flight hardware during ground handling and transportation so that environmental conditions do not exceed flight or orbital conditions

c. **Shall** comply with all NRL and range safety requirements for design safety factors, non-destructive evaluation (NDE), and proof testing

3.7.1.1.1.9 Mechanism Subsystem. The mechanisms subsystem is needed to perform the necessary deployments and separations to achieve the S/C's operational configuration and provide precise adjustment capability for spin balance and solar torque. Specifically the mechanisms subsystem:

a. **Shall** perform the necessary deployments and separations to achieve the S/C's operational configuration and provide precise adjustment capability for spin balance and solar torque

a. **Shall** interface with the ELV such that a highly reliable ELV-to-F/V separation system is achieved

b. **Shall** provide a highly reliable S/C to interstage separation system

c. **Shall** provide multi-use, cleanliness covers to protect the star trackers during S/C integration and testing, field operations, launch, and AKM burns

d. **Shall** provide a highly reliable system for deploying the solar array arm assemblies

e. **Shall** provide trim mass mechanisms with the capability to adjust the center of mass and spin axis misalignment[2]

f. **Shall** provide trim tabs with the capability to adjust the solar precession torque and thereby control the precession rate[3]

3.7.1.1.1.10 Radio Frequency Subsystem. The RFS:

a. **Shall** receive continuous 2 kbps uplink commands in any S/C bus orientation and rotation up to 60 rpm.

b. **Shall** provide low rate (approx. 1 kbps) minimum telemetry for emergency safe-hold and initial acquisition operations at any S/C orientation and rotation up to 60 rpm.

c. **Shall** provide continuous high rate (up to 409 kbps) data downlink in any S/C bus orientation.

d. **Shall** provide coherent spacecraft range and range rate capability.

e. **Shall** be compatible with NASA (STDN) ground stations.

f. **Shall** employ CCSDS compatible convolutional encoding on downlink r=1/2, k=7.

g. **Shall** comply with NTIA frequency management regulations.

h. Link margin **shall** show 5 dB or better margin worst case for all link analyses using a threshold of $1x10^{-6}$.

i. System residual bit error rate (strong signal) **shall** be $1x10^{-9}$ or better for science data downlink and $1x10^{-7}$ or better for low rate data and uplink.

3.7.1.1.1.11 Reaction Control Subsystem. The RCS configuration:

a. **Shall** provide spin jets about the observatory Z-axis

b. **Shall** provide 3-axis attitude control for all FV and observatory mission phases including pointing slew maneuvers, spin-up, spin axis precession (SAP), active nutation control (ANC), spin down, and attitude control during the on-board delta velocity maneuvers.

c. **Shall** provide total delta velocity between the AKM drop-off orbit, GEO mission orbit, and final observatory disposal orbit of 22 m/sec [TBR].

d. **Shall** perform spin axis ANC during the spin stabilized AKM firing.

3.7.1.1.1.12 S/C Bus Structures.

a. The structures subsystem **shall** provide a load path for all load cases encountered during the mission.

b. The primary structure:

(1) **Shall** provide sufficient area for solar power collection

(2) **Shall** provide sufficient thermal radiating surfaces for the electrical components

(3) **Shall** provide adequate shielding from particle radiation for the electronic components

3.7.1.1.1.12.1 Operational Envelope. The structures subsystem **shall** provide shade from the sun's rays for the instrument P/L during the operational observing and data collection configuration.

3.7.1.1.1.12.2 Instrument Interface. The structures subsystem **shall** provide a structural interface for the S/C bus to instrument payload as defined as defined in the FAME Instrument to S/C Bus ICD.

3.7.1.1.1.13 Thermal Control Subsystem.

3.7.1.1.1.13.1 Thermal Design.

a. The TCS **shall** provide autonomous thermal control of the observatory through passive thermal control by using radiators, multi-layer insulation (MLI) blankets, and thermostatically controlled, variable dissipation heaters.

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2. Note: Adjustments will not be made during the science stellar mapping mission phases.
3. Note: Adjustments will not be made during the science stellar mapping mission phases.

b. The TCS **shall** maintain the S/C bus, star tracker cameras, and S/C bus-to-instrument interface at a constant temperature using variable heater control and passive surfaces with consistent optical properties and well-understood degradation mechanisms and rates.

c. Mechanical thermostats **shall** be used on survival heater circuits.

d. Solid-state thermostats **shall** be used for both primary and variable heaters to minimize jitter during operational observing and data collection configuration.

e. All primary heater circuits **shall** be redundant.

f. The TCS **shall** provide 5˚C acceptance margins beyond temperatures predicted by an analytical thermal math model, and the math model will be correlated via Thermal Design Verification Test (TDVT).

3.7.1.1.1.13.2 Thermal Stability.

a. The TCS **shall** provide thermal stability to the S/C bus so as not to preclude the ACS system from meeting mission requirements. [TBR]

b. Heat-dissipating electronics boxes **shall** be mounted inside the S/C bus with support equipment evenly distributed on the S/C bus's internal decks. [TBR]

c. The electronics deck temperature **shall** be controlled to 15˚C ±30˚C.

d. The battery temperature **shall** be controlled to 15˚C ±10˚C.

e. Radiation torque **shall** be distributed evenly over the solar array/sun shield to provide stability for the ACS.

f. Surface temperatures **shall** be maintained at a nearly constant temperature where practical, while minimizing any thermal gradients.

3.7.1.1.2 Instrument Requirements.

3.7.1.1.2.1 Separated Fields of View. The FAME instrument **shall** consist of a single telescope fed by two FOV separated by a basic angle in the plane perpendicular to the observatory symmetry axis.

3.7.1.1.2.2 Basic Angle Stability. The basic angle of the FAME instrument **shall** vary by no more than +/- 50 picorad/minute.

3.7.1.1.2.3 Aperture Shape. The FAME instrument apertures **shall** be rectangular.

3.7.1.1.2.4 Magnitude Range of Observations. The FAME instrument **shall** be designed to observe average stars in the magnitude range of $5 \le m_v \le 15$.

3.7.1.1.2.5 Photometry. The FAME instrument **shall** be designed to make photometric observations in four bandpasses.

3.7.1.1.2.6 Spectral Response. The instrument spectral response shall be at or above the total efficiency levels defined in Table 3-6.

Table 3-6. Instrument Spectral Response

Wavelength (nm)	Efficiency
400	TBD
500	TBD
600	TBD
700	TBD
800	TBD
900	TBD

3.7.1.1.2.7 Telescope Focal Length. The focal length of the FAME telescope **shall** be 15.0 ±0.1 meters.

3.7.1.1.2.8 Overall Optical Quality. The FAME optical system shall have a total wavefront error of $<0.05\ \lambda$ at $\lambda = 650$ nm (TBR).

3.7.1.1.2.9 Optical Quality in Spherical Aberration. The total wavefront error due to 3rd order spherical aberration shall be <0.025 λ at λ = 650 nm (TBR).

3.7.1.1.2.10 Optical Quality in Coma. The total wavefront error due to 3rd order coma along the in-scan axis shall be <0.033 λ at λ = 650 nm (TBR).

3.7.1.1.2.11 Field of View. The telescope field of view shall be 1.1° in diameter.

3.7.1.1.2.12 Distortion. The system distortion shall be TBD.

3.7.1.1.2.13 Opto-Thermal-Mechanical Stability. TBD

3.7.1.1.2.14 Electronic Noise. TBD

3.7.1.1.2.15 Operational Waveband. The FAME instrument **shall** have an operational waveband of 0.4 - 0.9 μm.

3.7.1.1.2.16 Detectors. The focal plane of the FAME telescope **shall** contain 24 independent CCDs arranged to maximize the astrometric resolution and accuracy. There shall be 4 CCDs with photometric filters, 3 CCDs with neutral density filters of density TBD, and 3 CCDs with neutral density filters of density TBD.

3.7.1.1.2.17 Focal Plane Alignment to S/C Spin Axis. The CCDs on the focal plane of the instrument telescope **shall** be aligned to the observatory geometric axis to within 0.5 milliradians (2 pixels over 4096) by means of an instrument alignment cube. [TBR]

3.7.1.1.2.18 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 NCST-ICD-FM001, *FAME Instrument to Spacecraft Bus ICD*.

3.7.1.1.2.19 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 NCST-ICD-FM001, *FAME Instrument to Spacecraft Bus ICD*.

3.7.1.1.2.20 Attitude Determination. The instrument **shall** internally determine its fine attitude and rotation rate using an initial coarse attitude supplied by the S/C bus.

3.7.1.1.2.21 Data Windows. The instrument **shall** collect star observation data in 10 x 20 pixel windows.

3.7.1.1.2.22 Binning. With the exception of grid and predefined science stars, all stars **shall** be binned in the cross-scan direction by 20 in the CCD summing well.

3.7.1.1.2.23 Location of PSF Peak. The peak of the each star's PSF **shall** be contained in the central [4 pixels of a 10 x 20 pixel window].

3.7.1.1.2.24 Instrument Ground Support Equipment.

a. The instrument P/L supplier **shall** provide access to GSE that will enable functional tests, alignment verification, and calibration and characterization of the instrument during S/C bus to instrument P/L Mission Systems Integration and Test (MS&IT).

b. GSE provided by the instrument P/L supplier **shall** include the capability of commanding the instrument P/L, collecting several gigabytes of raw or simulated image data, and verifying the alignment of the instrument P/L using appropriate optical hardware. This same GSE will be used throughout S/C bus integration at NRL and for launch support operations.

c. The instrument GSE **shall** communicate with the S/C GSE during system integration and testing.

3.7.1.2 Interstage Assembly. The FAME interstage assembly **shall** consist of the interstage adapter (see paragraph 3.7.1.2.1) and the AKM (see paragraph 3.7.1.2.2).

3.7.1.2.1 Interstage Adapter. The interstage adapter:

a. **Shall** provide a load path for all load cases encountered during the mission.

b. **Shall** provide a structural interface for the FV to the ELV as defined in the FAME S/C Bus to ELV ICD.

3.7.1.2.2 Apogee Kick Motor. The FV AKM **shall** provide the total delta velocity between the Delta [2925-10] GTO and the mission GEO of 1478 m/sec [TBR].

3.7.2 Observatory Ground Segment. The following general requirements apply to all ground segment elements.

3.7.2.1 Operational Concept. The MOC (located at Blossom Point, MD) and the SOC (located at the USNO in Washington, DC) will be connected by a dedicated T1 (1.544 Mb/s) data link. After launch, the MOC will have primary responsibility for S/C bus management, including development of operational timelines, command sequences, and uplinks. The MOC will receive instrument command sequences (packets) from the SOC and, after verification, queue them for uplink based on times appended to the command sequences by the SOC. The MOC will distribute decommutated science data and instrument SOH data products to the SOC. All instrument activities will be planned and managed at the SOC. Once per week, the SOC will transfer a weekly plan file to the MOC. The plan file will contain the schedule of events for instrument operations and the command sequences to be uplinked. The MOC will receive this file and validate that it was not corrupted during ground transmission. Each day's sequence of events will be stored in the ground station queue to be uplinked via the dedicated BP antenna. Regular communications, such as catalog updates, will be uplinked using scheduled daily updates to simplify operations. However, because the S/C is in view at all times, uplinks can be implemented as necessary. The SOC will analyze S/C science data in near real-time to monitor image detection, image quality, and satellite attitude. The raw science data, along with various intermediate products, are archived, reduced, and analyzed to produce mission science deliverables, which include the FAME catalog of the astrometric and photometric parameters for each of the 40 million stars observed during the mission.

3.7.2.2 Wide Area Networking. The FAME mission will use two ground communication network paths. Both networks will use dedicated T1 data links (1.544 Mb/s) with commercial off-the-shelf (COTS) communications protocols and network routers. No COMSEC or data encryption will be required.

a. *Early On-Orbit Operations:* The first data path, used during launch and the early orbit period, consists of a dedicated T1 link between BP and the NASA Integrated Services Network (NISN) via GSFC. This path will enable data transfer of S/C telemetry and tracking data from NASA's DSN antennas at Madrid, Goldstone, and Canberra to BP. It also will enable throughput commanding from BP to DSN sites. This link is exercised during the pre-launch phase for compatibility tests.

b. *Operations:* The second communications path will be a dedicated T1 link between BP and USNO's SOC. BP will parse S/C and instrument telemetry data and mission science data into separate data streams and forward the data to the SOC. The S/C bus is monitored at the MOC. This network link will be active throughout the mission.

c. *Computer Security:* Both T1 data links will use dedicated connections to maintain secure data transfers. The link to the FAME public Internet web site from the SOC is isolated from both T1 links via an "air gap" (i.e., no physical connection exists between them). A secure firewall is maintained between the SOC and the public Internet and password protection will implemented. All system accesses will be logged and monitored to detect intrusion attempts. A periodic computer security testing program will assess vulnerabilities.

3.7.2.3 Command, Control, and Communications Facilities.

a. *Telemetry Downlink:*

(1) The GDS **shall** receive a continuous CCSDS packetized data stream from the S/C Bus at a [409.6 kbps] rate. These packets will consist of commutated wideband science data and narrowband SOH engineering data for the instrument and S/C bus.

(2) The S-Band downlink receiver **shall** demodulate the BPSK downlink data stream.

(3) The GDS **shall** provide a $<10^{-8}$ bit error rate (BER) with a [TBD%] data availability.

b. *Command Uplink:*

(1) The GDS **shall** provide an uplink data rate sufficient to update 1˚ x 1˚ tiles comprising the star catalog. Assuming a nominal 2 kbps uplink data rate, a single tile can be updated in <1 minute.

(2) The S-Band command uplink **shall** be PCM/PSK/PM modulated with a 16 kHz subcarrier to provide compatibility with NASA DSN stations for launch and GTO injection.

(3) Command data processing **shall** support uplink to the S/C per CCSDS COP-1 protocols.

(4) S/C command reception and execution **shall** be monitored and verified through downlinked COP-1 telemetry.

(5) The GDS **shall** support the S/C's three command modes: real-time, ground preplanned, and onboard scheduling based on uplinked command loads.

(6) The GDS **shall** provide a BER $<10^{-6}$.

3.7.2.3.1 Blossom Point Tracking Facility.

a. The NRL BPTF, located in Blossom Point, MD **shall** serve as the primary ground station facility and the MOC.

b. The MOC **shall** be configured to support all phases of on-orbit operations.

c. BPTF **shall** include a dedicated 11.3 m antenna system.

d. Antenna system upgrades **shall** include a reflector, pedestal, controller, and dual transmitters. Other facility upgrades will include a dedicated server and workstations.

e. The MOC **shall** provide the capability to monitor the on-orbit observatory, including capabilities, limit checking, trending analysis, and inference engine rules functions.

f. The MOC **shall** verify command execution, analyze results, investigate anomalies, and respond to off-nominal situations.

g. Realtime SOH data **shall** be automatically limit-checked, and out-of-limits conditions **shall** be flagged on the operator display and logged.

h. The MOC **shall** perform systems status analysis, including the review and generation of trend plots for key parameters and consumables. All out-of-limits conditions or unexpected changes in trend slopes **shall** be investigated and resolved by the MOC.

i. The MOC **shall** initiate safing measures whenever it is determined that a critical event seriously jeopardizes the mission if it were to continue to operate beyond defined and acceptable operating limits.

j. The MOC **shall** meet the tracking requirement for range noise = 3 m, range bias = 15 m, and range-rate noise = 3 mm/sec.

k. The MOC **shall** comply with CCSDS 101.0-B-3 recommendations for telemetry channel coding.

l. The MOC **shall** provide STDN-compatible command uplink data as BPSK command data at 2 kb/s with NRZ-M encoding.

m. The MOC **shall** be staffed to support the observatory on a 365/24/7 basis.

n. Mission simulations and rehearsals **shall** be conducted prior to launch for the MOC and SOC.

o. The MOC's GDS **shall** be sized to ingest the [409.6 kbps] continuous data rate, buffer and store the raw data, and forward science data and instrument housekeeping data packets to the SOC in realtime.

p. Raw wideband data **shall** be archived for playback purposes. The daily data volume will be approximately 4.3 GB, while a weekly archive data volume is approximately 30 GB.

3.7.2.3.2 Deep Space Network.

a. NASA's DSN sites at Goldstone, Madrid, and Canberra will augment the BPTF contact times for the first 7 days of the mission to maintain constant communications between the observatory and the flight operations team. The DSN sites will be used in a "bent pipe" mode for telemetry, tracking, and commanding. After the launch phase, DSN support will be on an "as-requested" basis to serve as an alternate command and control site. A serial communications link between BPTF and GSFC/NISN will be implemented to allow telemetry and tracking data received at any DSN site to be routed in realtime to BPTF. Likewise, command data will flow from BPTF through the serial link and directly up to the S/C via the supporting DSN antenna.

b. NRL will develop and submit a Project Service Level Agreement (PSLA) and a Detailed Mission Requirements (DMR) between NASA DSN and the FAME PMO.

3.7.2.3.3 Science Operations Center. The observatory SOC will be located on the grounds of the USNO in Washington, DC. The SOC monitors and operates the observatory instrument during the science operations phase of the mission. The SOC is responsible for producing the mission science deliverables which that the accuracies set in the *FAME Science Requirements Document* (NCST-D-FM001). In addition, the SOC:

a. **Shall** provide near real-time assessment of observatory science data quality through a First Look and Troubleshooting data ingestion pipeline.

b. **Shall** develop an astrometric/photometric mission data simulator to test and verify correct operation of the astrometric/photometric data reduction pipeline.

c. **Shall** operate an astrometric/photometric data reduction pipeline using raw observational S/C data to produce the mission science deliverables.

d. **Shall** archive the data streams received from the MOC together with critical intermediate products of the astrometric/photometric data analysis pipeline.

e. **Shall** provide the FAME science deliverables, including the FAME Input Catalog and FAME Science Catalog(s), which meet the photometric and astrometric accuracies set in the FAME Science Requirements Document (NCST-D-FM001). The initial FAME Science Catalog shall be delivered 1 year after completion of the baseline mission. The final FAME Science Catalog shall be delivered 1 year after completion of the extended mission.

3.7.2.4 Ground Software Systems.

3.7.2.4.1 Mission Operations Center. The MOC software and processing architecture will rely on COTS products. The MOC software **shall** adhere to industry standards for telemetry and command databases, and command and control. All software used for operational control purposes will follow a structured software engineering development process that uses spiral build implementation deploying multiple builds with increasing functionality.

3.7.2.4.2 Deep Space Network. NASA's DSN software and processing architecture will be defined in a DMR between NASA DSN and the FAME PMO.

3.7.2.4.3 Science Operations Center. The SOC software and processing architecture will rely on COTS products to maximum extent practical. Each of the SOC software subsystems will adhere to standards set forth in the FAME Data Analysis Software Development Plan (USNO document number TBD). The SOC software will include the FAME data simulator, astrometric and photometric pipeline, and the First Look and Troubleshooting Pipeline.

4.0 QUALITY ASSURANCE (QA) PROVISIONS

4.1 General. This section describes the analyses, tests, and inspections required for the observatory verification process. Verification of observatory design, construction, and performance will assure that the hardware and software conform to the requirements stated herein. The preferred method is test, where practical, to obtain empirical data to support verification. However, to meet observatory program technical, schedule, and cost objectives, reuse of previously qualified flight equipment may dictate use of other verification methods (e.g., inspection, analysis, and review of design documentation). NRL will implement a quality assurance program according to the requirements of NCST-D-FM005, *FAME Product Assurance Plan*, to verify compliance with specified requirements. The analyses, tests, and inspections specified in Table 4-1 (included at the end of this section) will be conducted to verify that all requirements specified in Section 3.0 have been achieved. Test requirements shall be as stated herein with planning information documented in NCST-TP-FM001, *FAME Test Plan*.

4.1.1 Responsibility for Tests. Each observatory component supplier will perform all or any of the verification requirements of this specification as directed in the purchasing documentation. Except as otherwise specified, the supplier may use its own or any other facilities suitable for performance of the inspection and test requirements specified herein, unless disapproved by the government. The FAME PMO reserves the right to perform any tests or inspections set forth herein when deemed necessary to ensure that supplies and services conform to prescribed requirements. Ultimate responsibility for proper operation of each component or subsystem remains with the NRL subsystem manager. NRL's product assurance team is responsible for maintaining a quality assurance system that offers maximum assistance to the subsystem manager.

4.2 QA Requirements. The NRL quality assurance program shall provide control of areas such as reliability; materials, processes, and parts; workmanship, etc. as provided by NCST-D-FM005, FAME Product Assurance Plan:

4.2.1 Control of Nonconforming Material. NRL's procedure for control of nonconforming material is defined in NCST-MQA-001, *Manual for Quality Assurance Procedures*. Nonconforming material shall be stored in a controlled area until disposition can be made.

4.2.2 Use of Nonconforming Material. Nonconforming material shall not be used without approval. All nonconforming material used in the final product shall be adequately documented per NCST-MQA-001, *Manual for Quality Assurance Procedures*.

4.3 Verification and Verification Documentation. The requirements of Section 3.0 shall be verified by one or more of the methods detailed in the Verification Requirements Checklist (Table 4-1).

a. Similarity;

b. Analysis;

c. Inspection;

d. Validation of Records;

e. Demonstration and Measurement;

f. Simulation;

g. Review of Design Documentation; and

h. Test.

Verification will be documented using the Verification Matrix. The matrix will include a separate record for each paragraph. Each record will include the requirement, verification description, compliance data, and approval block. All verification documentation will be made available to inspection, test, and assessment personnel. Applicable verification drawings, specifications, and procedures will be physically located at the verification site at the time of the verification event.

4.3.1 Verification by Similarity. Verification by similarity is a method of verification that verifies a requirement based on existing results from components and assemblies of like kind and includes a review of prior relevant hardware configurations and applications. Hardware of similar design and manufacturing process that have been qualified to equivalent or more stringent specifications may be verified by similarity.

4.3.2 Verification by Analysis. A method of verification, taking the form of the processing and accumulated results and conclusions, intended to provide proof that verification of a requirement(s) has been accomplished. The analytical results may be based on engineering study, compilation or interpretation of existing information, similarity to previously verified requirements, or derived from lower level examinations, tests, demonstrations, or analyses. Analyses will be performed as specified in Table 4-1 to verify applicable requirements of Section 3.0. The analytical methods that may be used include engineering analyses in the specified technical discipline, similarity to a previously verified requirement, review of drawings and data, use of experience, or prior testing. When an analysis is specified in Table 4-1, a detailed engineering study to verify compliance with Section 3.0 of this document will be performed and documented.

4.3.3 Verification by Inspection. An element of verification consisting of investigation, without the use of special laboratory appliances or procedures, to determine compliance with requirements. Examination is nondestructive and includes (but is not limited to) visual inspection, simple physical manipulation, gauging and measurement. Inspections will be performed as specified in Table 4-1 to verify applicable requirements of Section 3.0. These inspections are to be performed before unit qualification or acceptance testing as part of the normal quality control inspection process.

4.3.4 Validation of Records. Validation of records is a method of verification that consists of a systematic review of all relevant records to demonstrate compliance with a requirement. This method occurs as part of the hardware and software buy-off process. For requirements verified by this method, the approved buy-off package will serve to certify verification.

4.3.5 Demonstration or Measurement. A method of verification that is limited to readily observable functional operation to determine compliance with requirements. This method will not require the use of special equipment or sophisticated instrumentation.

4.3.6 Simulation. Verification by simulation is a process of verifying a requirement through the use of a representative device or system that emulates the behavior of a device or system to be verified. This method is often used when direct measurements is not possible.

4.3.7 Review of Design Documentation. 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.

4.3.8 Verification by Test. A method of verification that employs technical means, including (but not limited to) the evaluation of functional operation by use of special equipment or instrumentation, simulation techniques and the application of established principles and procedures, to determine compliance with requirements. The analysis of data derived from test is an integral part of this verification method.

Verification performed by test will be conducted according to NCST-TP-FM001, *FAME Test Plan*. Criteria and procedures for critical parameters monitoring during test will be developed and include, as appropriate, test chamber temperature, test article temperature, pressure, test voltages and currents, test acoustic spectrum and level, test vibration spectrum and level, illumination, particle or radiation flux, instrument response and telemetry, and contamination. The Observatory program will reuse existing hardware to the maximum extent possible and as such will verify selected design requirements via previous qualification test data rather than retest. NCST-TP-FM001, *FAME Test Plan*, provides a verification matrix delineating the specific verification methods to be used. The Observatory program will use the four types of tests specified below:

a. Functional tests to verify in an abbreviated fashion that the unit or system is functioning;

b. Performance tests to demonstrate and quantify the specified electrical and mechanical performance parameters of the unit or system;

c. Qualification tests to verify inherent functional performance capabilities in excess of the design requirements over the specified environment, including special interface qualification tests performed at KSC or NRL using flight equivalent units; and

d. Acceptance tests to gain confidence that each unit has achieved the inherent design capability verified on a sample basis.

4.3.8.1 Functional/Performance Tests. Functional or performance tests will be performed before, during, and after environmental exposures as part of the acceptance and qualification test sequences. This performance check will be made according to approved test procedures. A record will be made of all data necessary to determine complete operational and performance characteristics.

4.3.8.2 Software Verification Tests. Existing test automation and requirements traceability software will be used to the maximum practical extent in support of verification activities. Test software interfacing with flight hardware will be verified prior to verification tests.

4.3.8.3 Independent Validation of Computer Programs. All computer programs performing on-line mission-critical operational functions in any observatory system segment will be subject to an independent verification and validation (IV&V).

4.3.8.4 Environmental Tests.

4.3.8.4.1 Development Tests. Development tests are not required; however, it is the responsibility of each subsystem manager to conduct sufficient tests or analysis as necessary to minimize risks to the program. Development tests or analyses that are performed will be documented.

4.3.8.4.2 Acceptance Tests. Acceptance tests will be conducted to demonstrate acceptability of an item for movement to the next stage of testing or buy-off. Acceptance tests are intended to act as a quality screening and process control tool to detect deficiencies of workmanship, material, and quality. The following acceptance tests shall be performed as detailed in Table 4-1.

4.3.8.4.2.1 Acoustics. Tests will be conducted to verify compliance with paragraph 3.2.5.2.1 as detailed in NCST-TP-FM001, *FAME Test Plan.*

4.3.8.4.2.2 Random Vibration. Tests will be conducted to verify compliance with paragraph 3.2.5.2.1 as detailed in NCST-TP-FM001, *FAME Test Plan.*

4.3.8.4.2.3 Thermal Vacuum. Tests will be conducted to verify compliance with paragraph 3.2.5.2.2 as detailed in NCST-TP-FM001, *FAME Test Plan.*

4.3.8.4.2.4 Pyrotechnic Shock. Live firing tests will be conducted (to the maximum extent possible) to verify compliance with paragraph 3.2.5.2.1 as detailed in NCST-TP-FM001, *FAME Test Plan.*

4.3.8.4.3 Qualification Tests. Qualification tests will be conducted to demonstrate that the design and manufacturing methods used in the construction of the Observatory have resulted in an item that meets the specified requirements and has suitable margins when exposed to the expected operating environments. The following qualification tests shall be performed as detailed in the Verification Requirements Checklist (Table 4-1).

4.3.8.4.3.1 Modal Survey. Tests may be conducted to achieve agreement between the analytical structural model and the space segment structure as detailed in NCST-TP-FM001, *FAME Test Plan.*

4.3.8.4.3.2 Vibration. Verification will be conducted to assure compliance with paragraph 3.2.5.2.1 as detailed in NCST-TP-FM001, *FAME Test Plan.*

4.3.8.4.3.3 Acoustics. Verification will be conducted to assure compliance with paragraph 3.2.5.2.1 as detailed in NCST-TP-FM001, *FAME Test Plan.*

4.3.8.4.3.4 Pyrotechnic Shock. Verification will be conducted to assure compliance with paragraph 3.2.5.2.1 as detailed in NCST-TP-FM001, *FAME Test Plan.*

4.3.8.4.3.5 Thermal Vacuum. Tests will be conducted to verify compliance with paragraph 3.2.5.2.2 as detailed in NCST-TP-FM001, *FAME Test Plan.*

4.3.8.4.3.6 Thermal Balance. Tests will be conducted to verify the Observatory thermal design at the component level as detailed in NCST-TP-FM001, *FAME Test Plan.*

4.3.8.4.3.7 EMI/EMC. Tests will be conducted to verify compliance with paragraph 3.3.2 as detailed in NCST-TP-FM001, *FAME Test Plan.*

4.3.9 Verification of Safety Requirements. Safety related requirements will be verified as part of the range safety process.

Table 4-1. Verification Requirements Checklist

Design Requirements		Verification Method								
Paragraph No.	Title	Not Applicable	Similarity	Analysis	Inspection	Validation of Records	Demonstration or Measurement	Simulation	Review of Design Documentation	Test
3.0	REQUIREMENTS	X								
a.		X								
b.		X								
3.1	FAME Mission Requirements	X								
3.1.1	Mission Concept	X								
3.1.2	FAME Mission Diagram	X								
3.1.2.1	Flight Vehicle Description	X								
3.1.2.1.1	FAME Observatory			X						
3.1.2.1.1.1	S/C Bus	X								
3.1.4.1.1.2	Instrument Payload	X								
3.1.2.1.2	FAME Interstage Assembly	X								
3.1.2.2	Ground Segment			X						X
3.1.3	3.1.3	X								
3.1.3.1	Flight Vehicle to ELV Interface	X								
3.1.3.2	Space Segment (Flight Vehicle) to Ground Data System Interface	X								
3.1.3.3	Internal Interfaces	X								
3.1.4	Major Component List	X								
3.1.4.1	Space Segment (Flight Vehicle)	X								
3.1.4.1.1	FAME Observatory	X								
3.1.4.1.1.1	FAME S/C Bus	X								
3.1.4.1.1.2	Instrument Payload	X								
3.1.4.1.2	Interstage Assembly	X								
3.1.4.2	Ground Segment	X								
3.1.5	Government Furnished Equipment List	X								
3.1.6	System Operations Concept	X								
3.1.6.1	Pre-Launch Operations	X								
3.1.6.2	Launch and Ascent Operations	X								
3.1.6.3	Geosynchronous Transfer Orbit (GTO) Operations	X								
3.1.6.4	Supersynchronous Orbit Operations	X								
3.1.6.5	Science Operations	X								
3.1.6.6	Disposal Operations	X								
3.2	Performance Requirements and Physical Characteristics	X								

Table 4-1. Verification Requirements Checklist (Continued)

Design Requirements		Verification Method								
Paragraph No.	Title	Not Applicable	Similarity	Analysis	Inspection	Validation of Records	Demonstration or Measurement	Simulation	Review of Design Documentation	Test
3.2.1	Performance Requirements	X								
3.2.1.1	Flight Vehicle			X						
3.2.1.1.1	Observatory			X						
3.2.1.1.1.1	S/C Bus Characteristics and Performance Requirements	X								
3.2.1.1.1.1.1	S/C Bus Characteristics	X								
3.2.1.1.1.1.2	S/C Bus Performance Requirements			X						
a.				X						
b.		X								
c.				X						
d.		X								
e.		X								
f.		X								
g.		X								
h.				X						X
i.		X								
j.		X								
k.		X								
3.2.1.1.1.2	Instrument Characteristics and Performance Requirements	X								
3.2.1.1.1.2.1	Instrument Characteristics	X								
3.2.1.1.1.2.1.1	Instrument Optical Subsystem	X								
3.2.1.1.1.2.1.2	Instrument Focal Plane Assembly	X								
3.2.1.1.1.2.1.3	Instrument Structure	X								
3.2.1.1.1.2.1.4	Instrument Thermal Control	X								
3.2.1.1.1.2.1.5	Instrument Electronics, Software, and Data Processing	X								
3.2.1.2	Ground Segment	X								
3.2.1.2.1	Ground Segment Performance Characteristics	X								
3.2.1.2.2	Ground Segment Performance Requirements	X								
3.2.1.2.2.1	Mission Operations Center	X								
a.				X	X				X	
b.				X	X				X	X
3.2.1.2.2.2	NASA's Deep Space Network Support Complexes	X								

Table 4-1. Verification Requirements Checklist (Continued)

Design Requirements		Verification Method								
Paragraph No.	Title	Not Applicable	Similarity	Analysis	Inspection	Validation of Records	Demonstration or Measurement	Simulation	Review of Design Documentation	Test
3.2.1.2.3	FAME Science Operations Center	X								
3.2.2	Physical Characteristics	X								
3.2.2.1	Mass Properties									
a.				X	X				X	
b.									X	
3.2.2.2	Dimensions and Envelope									
a.				X						
b.				X						
c.									X	
d.				X						
3.2.2.3	Coordinate System	X								
3.2.3	System Quality Factors	X								
a.									X	
b.				X						
3.2.3.1	Failure Modes and Effects Analysis (FMEA)			X					X	
3.2.3.2	Electrical Stress Analysis			X						
3.2.3.3	Reliability	X								
a.				X						
b.				X						
c.				X						
d.				X						
e.				X						
3.2.3.4	Single Point Failures	X								
a.				X						
b.				X						
c.				X						
3.2.3.5	Redundancy	X								
a.				X						
b.				X						
3.2.3.6	Worst Case Analysis	X								
a.				X						
b.				X						
c.				X						

Table 4-1. Verification Requirements Checklist (Continued)

Design Requirements		Verification Method								
Paragraph No.	**Title**	**Not Applicable**	**Similarity**	**Analysis**	**Inspection**	**Validation of Records**	**Demonstration or Measurement**	**Simulation**	**Review of Design Documentation**	**Test**
3.2.4	Systems Effectiveness Models	X								
a.				X						
b.				X						
3.2.5	Environmental Conditions	X								
a.				X						
b.				X	X					
c.				X						
3.2.5.1	Non-Operating Environment			X						
3.2.5.1.1	NRL Integration and Test Facility Environment			X						X
a.		X								
b.		X								
c.		X								
d.		X								
e.		X								
3.2.5.1.2	Ground Handling and Transportation			X						X
a.		X								
b.		X								
c.		X								
d.		X								
e.		X								
3.2.5.1.3	Prelaunch			X						X
a.		X								
b.		X								
c.		X								
d.		X								
e.		X								
3.2.5.2	Operating Environment			X						X
3.2.5.2.1	Launch and Ascent	X								
a.				X						X
b.				X					X	X
3.2.5.2.2	Orbital Operations			X						
3.2.5.2.2.1	Natural Thermal Radiation			X						
3.2.5.2.2.2	Pressure									X

Table 4-1. Verification Requirements Checklist (Continued)

Design Requirements		Verification Method								
Paragraph No.	Title	Not Applicable	Similarity	Analysis	Inspection	Validation of Records	Demonstration or Measurement	Simulation	Review of Design Documentation	Test
3.2.5.2.2.3	Particle Radiation			X						
3.2.5.2.2.3.1	Total Ionizing Dose	X								
a.				X						
b.				X						
3.2.5.2.2.3.2	Single Event Effects			X						
a.		X								
b.		X								
c.		X								
3.2.5.2.2.3.2.1	Single Event Induced Destructive Failure	X								
a.				X						
b.				X					X	
3.2.5.2.2.3.2.2	Single Event Induced Non-Destructive Failure	X								
a.				X						
b.				X					X	
3.2.5.2.2.3.2.3	Single Event Induced Soft Errors	X								
a.				X						
b.				X					X	
3.3	Design and Construction	X								
3.3.1	Parts, Materials, and Processes (PMP)								X	
a.				X						
b.		X								
c.				X	X				X	
d.						X				
3.3.1.1	EEE Standard Parts Selection Criteria	X								
a.				X						
b.				X					X	
3.3.1.2	EEE Parts Procurement, Processing, and Screening								X	
a.				X					X	
b.		X								
(1)				X					X	
(2)				X	X				X	
(3)				X					X	
(4)		X								

Table 4-1. Verification Requirements Checklist (Continued)

Design Requirements		Verification Method								
Paragraph No.	Title	Not Applicable	Similarity	Analysis	Inspection	Validation of Records	Demonstration or Measurement	Simulation	Review of Design Documentation	Test
(5)				X					X	
3.3.1.3	EEE Parts Stress Derating			X					X	
3.3.1.4	Electrostatic Discharge Sensitive EEE Parts	X								
a.				X	X					
b.						X			X	
3.3.1.5	Materials	X								
3.3.1.5.1	Outgassing	X								
a.				X					X	
b.									X	
3.3.1.5.2	Structural and Metallic Materials								X	
a.				X					X	
b.				X					X	
c.				X					X	
d.				X					X	
3.3.1.5.3	Magnetic Materials			X					X	
3.3.1.5.4	Finishes	X								
a.									X	
b.									X	
3.3.1.5.5	Toxic Products and Formulations			X					X	
3.3.1.5.6	Stress Corrosion			X					X	
3.3.1.5.7	Polymer Materials								X	
3.3.1.6	Processes	X								
3.3.1.6.1	Soldering and Other Processes								X	
a.									X	
b.									X	
c.					X				X	
d.					X				X	
e.					X				X	
3.3.1.6.2	Traceability Process								X	
a.									X	
b.									X	
(1)									X	
(2)									X	

Table 4-1. Verification Requirements Checklist (Continued)

Design Requirements		Verification Method								
Paragraph No.	Title	Not Applicable	Similarity	Analysis	Inspection	Validation of Records	Demonstration or Measurement	Simulation	Review of Design Documentation	Test
(3)									X	
c.									X	
d.									X	
(1)		X								
(2)		X								
(3)		X								
(4)		X								
3.3.1.6.3	Failure Reporting and Corrective Action System	X								
a.									X	
b.				X						
3.3.2	Electromagnetic Environment			X						
3.3.3	Corona Suppression			X						
3.3.4	Nameplate and Product Marking				X					
3.3.5	Workmanship	X								
a.									X	
b.					X					
3.3.6	Safety	X								
a.				X	X					
b.				X	X					
c.				X	X					
d.				X	X					
e.				X	X					
3.3.7	Human Performance and Human Engineering			X						
3.3.8	System Security	X								
a.				X						
b.				X						
3.3.9	Computer Resources	X								
a.				X						
(1)		X								
(2)		X								
(3)		X								
(4)		X								
b.									X	

Table 4-1. Verification Requirements Checklist (Continued)

Design Requirements		Verification Method								
Paragraph No.	Title	Not Applicable	Similarity	Analysis	Inspection	Validation of Records	Demonstration or Measurement	Simulation	Review of Design Documentation	Test
3.3.10	Standards of Manufacture	X								
3.3.10.1	Processes and Controls			X						
a.						X			X	
b.						X			X	
c.						X			X	
d.						X			X	
e.						X			X	
3.3.10.2	Production Lots	X								
a.					X					
b.					X	X				
c.						X				
d.					X					
3.3.10.3	Contamination Control and Cleanliness				X					
3.3.10.4	Connectors	X								
a.					X					
b.					X					
3.3.10.5	Positive Locking Devices	X								
a.					X					
b.					X					
3.4	Documentation								X	
3.4.1	Specifications	X								
3.4.2	Drawings	X								
a.									X	
b.									X	
3.4.3	Software Support Documentation								X	
3.4.4	Test Plans and Procedures								X	
3.5	Logistics	X								
3.6	Personnel and Training	X								
3.7	Major Component Characteristics	X								
3.7.1	FAME Flight Vehicle	X								
3.7.1.1	FAME Observatory	X								
3.7.1.1.1	FAME S/C Bus			X	X				X	
3.7.1.1.1.1	Attitude Determination and Control Subsystem	X								

Table 4-1. Verification Requirements Checklist (Continued)

Design Requirements		Verification Method								
Paragraph No.	Title	Not Applicable	Similarity	Analysis	Inspection	Validation of Records	Demonstration or Measurement	Simulation	Review of Design Documentation	Test
3.7.1.1.1.1.1	Spin Period			X				X		
3.7.1.1.1.1.2	Sun Angle			X				X		
3.7.1.1.1.1.3	Precession Period			X				X		
3.7.1.1.1.2	Command, Telemetry & Data Handling Subsystem	X								
a.										X
b.										X
c.										X
d.										X
e.										X
f.										X
g.										X
h.										X
i.										X
j.										X
k.										X
l.										X
m.										X
n.										X
o.										X
p.										X
3.7.1.1.1.3	Electrical Aerospace Ground Equipment	X								
a.										X
b.										X
c.				X				X		
d.							X			
e.								X		
f.										X
3.7.1.1.1.4	Electrical Power Subsystem (EPS)	X								
a.				X						X
b.				X						X
c.				X						X
d.				X						
e.				X						X

Table 4-1. Verification Requirements Checklist (Continued)

Design Requirements		Verification Method								
Paragraph No.	Title	Not Applicable	Similarity	Analysis	Inspection	Validation of Records	Demonstration or Measurement	Simulation	Review of Design Documentation	Test
f.				X						X
g.				X						
3.7.1.1.1.4.1	Ordnance Control Subsystem	X								
a.				X	X				X	X
b.				X	X					X
(1)				X	X					X
(2)				X	X					X
(3)				X	X					X
c.				X	X				X	
3.7.1.1.1.5	Flight Software	X								
a.				X						
b.		X								
(1)				X						
(2)										X
(3)				X						X
c.										X
d.										X
e.										X
f.										X
g.				X						
3.7.1.1.1.6	Ground Software	X								
a.										X
b.										X
c.										X
d.										X
e.										X
f.										X
g.										X
h.										X
i.										X
j.										X
k.										X
(1)										X

Table 4-1. Verification Requirements Checklist (Continued)

Design Requirements		Verification Method								
Paragraph No.	Title	Not Applicable	Similarity	Analysis	Inspection	Validation of Records	Demonstration or Measurement	Simulation	Review of Design Documentation	Test
(2)										X
(3)										X
l.										X
m.										X
n.										X
3.7.1.1.1.7	Harness Subsystem	X								
a.				X						X
b.				X						X
c.				X						X
3.7.1.1.1.8	Mechanical Aerospace Ground Equipment (MAGE)	X								
a.				X	X					
b.							X			
c.				X	X					X
3.7.1.1.1.9	Mechanism Subsystem	X								
a.				X						X
b.				X						X
c.				X						X
d.				X						X
e.				X						X
f.				X						X
3.7.1.1.1.10	Radio Frequency Subsystem	X								
a.										X
b.										X
c.										X
d.							X			X
e.							X			
f.										X
g.										X
h.				X						
i.										X
3.7.1.1.1.11	Reaction Control Subsystem			X						
a.				X						
b.				X						

Table 4-1. Verification Requirements Checklist (Continued)

Design Requirements		Verification Method								
Paragraph No.	Title	Not Applicable	Similarity	Analysis	Inspection	Validation of Records	Demonstration or Measurement	Simulation	Review of Design Documentation	Test
c.				X						
d.				X						
3.7.1.1.1.12	S/C Bus Structures	X								
a.				X	X				X	
b.		X								
(1)				X	X				X	
(2)				X					X	
(3)				X					X	
3.7.1.1.1.12.1	Operational Envelope			X	X				X	
3.7.1.1.1.12.2	Instrument Interface			X					X	
3.7.1.1.1.13	Thermal Control Subsystem	X								
3.7.1.1.1.13.1	Thermal Design	X								
a.				X						
b.				X						X
c.					X				X	
d.					X				X	
e.					X				X	
f.				X						X
3.7.1.1.1.13.2	Thermal Stability	X								
a.				X						X
b.				X	X				X	
c.				X						X
d.				X						X
e.				X						X
f.				X						X
3.7.1.1.2	Instrument Requirements	X								
3.7.1.1.2.1	Separated Fields of View				X					
3.7.1.1.2.2	Basic Angle Stability			X						
3.7.1.1.2.3	Aperture Shape				X					
3.7.1.1.2.4	Magnitude Range of Observations									
3.7.1.1.2.5	Photometry									
3.7.1.1.2.6	Spectral Response									X
3.7.1.1.2.7	Telescope Focal Length									X

Table 4-1. Verification Requirements Checklist (Continued)

Design Requirements		Verification Method								
Paragraph No.	Title	Not Applicable	Similarity	Analysis	Inspection	Validation of Records	Demonstration or Measurement	Simulation	Review of Design Documentation	Test
3.7.1.1.2.8	Overall Optical Quality									X
3.7.1.1.2.9	Optical Quality in Spherical Aberration									X
3.7.1.1.2.10	Optical Quality in Coma									X
3.7.1.1.2.11	Field of View									X
3.7.1.1.2.12	Distortion									X
3.7.1.1.2.13	Opto-Thermal-Mechanical Stability.			X						X
3.7.1.1.2.14	Electronic Noise									X
3.7.1.1.2.15	Operational Waveband									X
3.7.1.1.2.16	Detectors				X					
3.7.1.1.2.17	Focal Plane Alignment to S/C Spin Axis									X
3.7.1.1.2.18	S/C Antenna				X				X	
3.7.1.1.2.19	S/C Star Tracker Support				X				X	
3.7.1.1.2.20	Attitude Determination									X
3.7.1.1.2.21	Data Windows						X			
3.7.1.1.2.22	Binning						X			
3.7.1.1.2.23	Location of PSF Peak									X
3.7.1.1.2.24	Instrument Ground Support Equipment	X								
a.										
b.										
c.										
3.7.1.2	Interstage Assembly				X				X	
3.7.1.2.1	Interstage Adapter	X								
a.				X						
b.				X					X	
3.7.1.2.2	Apogee Kick Motor			X						
3.7.2	Observatory Ground Segment	X								
3.7.2.1	Operational Concept	X								
3.7.2.2	Wide Area Networking	X								
a.		X								
b.		X								
c.		X								
3.7.2.3	Command, Control, and Communications Facilities	X								
a.		X								

Table 4-1. Verification Requirements Checklist (Continued)

Design Requirements		Verification Method								
Paragraph No.	Title	Not Applicable	Similarity	Analysis	Inspection	Validation of Records	Demonstration or Measurement	Simulation	Review of Design Documentation	Test
(1)				X				X		X
(2)				X				X		X
(3)				X				X		
b.		X								
(1)				X				X		X
(2)				X				X		X
(3)				X				X		X
(4)				X				X		X
(5)				X				X		X
(6)				X				X		X
3.7.2.3.1	Blossom Point Tracking Facility	X								
a.				X						
b.				X						
c.				X						
d.				X						
e.				X				X		X
f.				X				X		X
g.				X				X		X
h.				X				X		X
i.				X				X		X
j.				X				X		X
k.				X				X		X
l.				X				X		X
m.				X			X			
n.							X	X		
o.				X				X		X
p.				X				X		
3.7.2.3.2	Deep Space Network	X								
a.		X								
b.		X								
3.7.2.3.3	Science Operations Center	X								
a.				X			X	X		X
b.				X			X			

Table 4-1. Verification Requirements Checklist (Continued)

Design Requirements		Verification Method								
Paragraph No.	Title	Not Applicable	Similarity	Analysis	Inspection	Validation of Records	Demonstration or Measurement	Simulation	Review of Design Documentation	Test
c.				X			X	X		X
d.							X	X		X
e.				X				X		
3.7.2.4	Ground Software Systems									
3.7.2.4.1	Mission Operations Center									
3.7.2.4.2	Deep Space Network									
3.7.2.4.3	Science Operations Center									

5.0 LIST OF ACRONYMS

ADC	Analog-to-Digital Converter
AKM	Apogee Kick Motor
ANC	Active Nutation Control
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
BPTF	Blossom Point Satellite Tracking Facility
C3	Command, Control, and Communications
CCD	Charge Coupled Device
CCSDS	Consultative Committee on Space Data Systems
CDR	Critical Design Review
COMSEC	Communications Security
COTS	Commercial Off-the-Shelf
CSCI	Computer Software Configuration Item
CVCM	Collected Volatile Condensable Material
DMR	Detailed Mission Requirements
DPA	Destructive Physical Analysis
DSN	Deep Space Network
EAGE	Electrical Aerospace Ground Equipment
EDAC	Error Detection and Correction
EEE	Electrical, Electronic, and Electromechanical
ELV	Expendable Launch Vehicle
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
FAME	Full-sky Astrometric Mapping Explorer
FMEA	Failure Mode and Effects Analysis
FOT	Flight Operations Team
FOV	Field of View
FPA	Focal Plane Assembly
FRACAS	Failure Reporting and Corrective Action System
FSC	FAME Spacecraft Controller
FSW	Flight Software
FV	Flight Vehicle
GDS	Ground Data System
GEO	Geosynchronous Earth Orbit
GFE	Government Furnished Equipment
GIDEP	Government-Industry Data Exchange Program
GSE	Ground Support Equipment
GTO	Geosynchronous Transfer Orbit
H&ST	Housekeeping and Status Telemetry
HMI	Human-Machine Interface
HWCI	Hardware Configuration Item
I&T	Integration and Test
ICD	Interface Control Document
IMU	Inertial Measurement Unit
IV&V	Independent Verification and Validation
kbps	Kilobits per Second
MAGE	Mechanical Aerospace Ground Equipment
MAR	MIDEX Assurance Requirements
mas	microarcseconds
MCCR	Mission Critical Computing Resource
MLI	Multi-Layer Insulation
MO&DA	Mission Operations and Data Analysis

MOC	Mission Operations Center
MRD	Mission Requirements Document
MS&IT	Mission Systems Integration and Test
NASTRAN	NASA Structural Analysis
NDE	Non-Destructive Evaluation
NFE	NASA Furnished Equipment
NISN	NASA Integrated Services Network
OCS	Ordnance Control System
OD	Orbit Determination
OSHA	Occupational Health and Safety Administration
P/L	Payload
PCB	Printed Circuit Board
PCDE	Power Control and Distribution Electronics
PDR	Preliminary Design Review
PIND	Particle Impact Noise Detection
PMO	Project Management Office
PMP	Parts, Materials, and Processes
PPF	Payload Processing Facility
PRACA	Problem and Corrective Action
PSLA	Project Service Level Agreement
QML	Qualified Manufacturer List
QPL	Qualified Parts List
R&QA	Reliability and Quality Assurance
RF	Radio Frequency
S/C	Spacecraft
SAP	Spin Axis Precession
SEE	Single Event Effects
SEFI	Single Event Functional Interrupts
SEMP	Systems Engineering Management Plan
SINDA85	Systems Improved Numerical Differencing Analyzer
SOC	Science Operations Center
SOH	State of Health
SPE	Solar Particle Event
SPF	Single Point Failure
SR&QA	Safety, Reliability, and Quality Assurance
SSIP	System Safety Implementation Plan
STDN	Space Tracking Data Network
TBD	To Be Determined
TBR	To Be Resolved
TCS	Thermal Control System
TDI	Time Delay Integration
TDVT	Thermal Design Verification Test
TID	Total Ionizing Dose
TML	Total Mass Loss
TRASYS	Thermal Radiation Analysis System
WCA	Worst Case Analysis

6.0 LIST OF OPEN ITEMS

6.1 Items Listed as "TBS" (To Be Supplied).

Table 6-1. Items Listed as TBS

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6.2 Items Listed as "TBR" (To Be Resolved).

Table 6-2. Items Listed as TBR

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