NAVAL RESEARCH LABORATORY

NAVAL CENTER FOR SPACE TECHNOLOGY

Full-Sky Astrometric Mapping Explorer (FAME)
Preliminary Safety Assessment

NCST-D-FM009 DRAFT **11 December 2000**

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RECORD OF CHANGES

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1. SCOPE

1.1 Identification.

This document applies to the Full-Sky Astrometric Mapping Explorer (FAME) Observatory.

1.2 Purpose.

This document serves as the preliminary assessment of the compliance with EWRR 127-1 and the FAME System Safety Implementation Plan (SSIP), NCST-D-FM010 for the FAME Observatory. The objective of this document is to describe the various subsystems and identify any potential hazards associated with personnel, facilities, support equipment, and flight hardware or software.

1.3 System Overview.

The FAME 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 (uas) at 9th visual magnitude and 500 mas 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.

1.4 Document Overview.

This document provides a detailed description and safety assessment report down to the subsystem level to ensure that the requirements of EWRR 127-1 and the FAME System Safety Implementation Plan (SSIP), NCST-D-FM010 are being met. It identifies the associated potential hazards and related controls to personnel, facilities, support equipment, and flight system during development, integration, test, and pre-launch activities. 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, *FAME Overview:* A general description of the FAME mission and description of the system.
- Section 4.0, *Flight System Detailed Description:* Detailed information on each major subsystem of the FAME Observatory.
- Section 5.0, *FAME Ground Support Equipment Detailed Description:* Detailed information on the FAME GSE.
- Section 6.0, *Ground Operations:* Information on operational flow, procedures, contingency operations, personnel safety equipment, and assessment of operations.
- Section 7.*0, Potential Hazards and Controls:* Assessment of potential hazards and controls to eliminate or mitigate hazards.

2. 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 Specifications.

Number	Title	Para Reference

2.1.2 Other Publications.

Number	Title	Para Reference
EWRR 127-1	Eastern and Western Range Regulation 127-1, Range Safety Requirements	

2.1.3 FAME Project Documents.

Number	Title	Para Reference
NCST-D-FM010	FAME System Safety Implementation Plan (SSIP)	

2.1.4 NCST Manuals.

Number	Title	Para Reference

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	Para Reference

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. FAME OVERVIEW

3.1 General System Description.

The principal requirement for the FAME observatory 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 500μas 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 a required mission life of 2.5 years (requirement) and an extended mission of up to 5 years (goal).

3.2 Space Segment.

The FAME observatory space segment consists of a spacecraft (S/C) bus and a single scanning survey instrument (referred to as Instrument or payload herein). The term "S/C bus" refers to the flight hardware/software required to support the payload (P/L). The term "observatory" refers to the S/C bus and the P/L. The term "Apogee Kick Motor" (AKM) refers to the observatory's Solid Rocket Motor (SRM) which is attached to the observatory. The term "Flight Vehicle" (FV) refers to the mated S/C bus, the P/L, and the AKM. The term "Expendable Launch Vehicle" (ELV) refers to the booster and/or launch services.

3.2.1 Spacecraft (S/C) Bus.

The primary requirements of the S/C bus are to place the P/L in the proper orbit; provide a long term stable platform for the P/L; and collect, buffer, format for downlink, and transmit the resulting science data to the Ground Data System (GDS). The S/C bus will be designed with a central thrust tube and structure to accommodate an AKM and a hydrazine propulsion system. 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 shall 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. 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 FAME mission will provide the positions, proper motions, parallaxes, and photometry of nearly all stars as faint as 15th visual magnitude with accuracies of 0.243 nanoradians (50 microarcseconds [μas]) at 9th visual magnitude and 2.43 nanoradians (500 μas) at 15th visual magnitude (m_v). 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 evolved from the *Hipparcos* mission with a mission life of 2.5 years and an extended mission to 5 years.

3.2.2 Instrument Payload.

The instrument shall achieve these objectives using a single telescope looking at two fields of view simultaneously. The two fields of view will be separated by a basic angle in the plane perpendicular to the rotation axis that has a value that is not near an integer factor of 360°. The telescope apertures shall be sized appropriately for observing average m_v=9 stars using exposure times equal to the time required for stars to transit across a CCD. The two fields of view will be imaged onto a single focal plane populated with CCDs. The CCDs will be clocked in time delay integration (TDI) (drift scan) mode to accumulate stellar images as the instrument rotates. A subset of the CCDs in the focal plane shall be allocated for observing average stars with $5 \leq m_v < 9$. Another subset of CCDs in the focal plane shall be allocated for photometric observations in 4 passbands.

All of the electronics to store and process the on-board input star catalog, as well as the electronics to operate the CCDs and to process the CCD outputs into digital format and to deliver that data to the S/C bus, shall be incorporated into the instrument.

Only the data from pixels around target stars shall be transmitted to the S/C bus for downlink. To accomplish this, the instrument shall store an on-board input star catalog and calculate which CCD pixels are to be read for downlink.

The instrument shall therefore be capable of determining the instrument's attitude using its own data from initial measurements provided by the S/C bus. The instrument shall also calculate the rotation rate of the observatory and shall have adjustable CCD TDI rates to compensate for variations in the observatory's rotation.

3.3 **Ground Segment.**

The ground segment shall (i) transmit commands to the observatory; (ii) receive and archive downlinked HS&T telemetry and science data; (iii) monitor and trend S/C bus and instrument HS&T data; (iv), and analyze and reduce science data to produce mission science deliverables.

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.

The MOC shall be responsible for day-to-day flight operations. All communications with the observatory will be via the MOC in all mission phases. All nominal communications 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.

The SOC shall be responsible for the P/L. 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.

3.4 **Mission Concept.**

The observatory uses a telescope looking at two FOV separated by a fixed basic angle. The S/C will rotate at a rate of once every 40 minutes and measure stars along a spiral. The rotation axis of the S/C precesses around the sun vector to scan the whole sky. FAME uses a CCD array with high quantum efficiency to determine transit times while simultaneously observing many stars. The CCDs will be used in a 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.

4. FLIGHT SYSTEM DETAILED DESCRIPTION

4.1 Structural/Mechanical Subsystems.

4.2 Mechanisms Subsystem.

4.3 Ordnance Control Subsystem.

4.4 Propulsion and Propellant Subsystem.

4.5 RF Communications Subsystem.

4.6 Electrical Power Subsystem.

4.7 Wiring Harness.

4.8 CT&DH.

4.9 ADCS.

4.10 THERMAL.

4.11 FAME INSTRUMENT.

5. GROUND SUPPORT EQUIPMENT DETAILED DESCRIPTION

6. GROUND OPERATIONS

7. POTENTIAL HAZARDS AND CONTROLS

8. ACRONYMS