

NAVAL RESEARCH LABORATORY
NAVAL CENTER
FOR
SPACE TECHNOLOGY

Full-Sky Astrometric Mapping Explorer (FAME)
Ground Software Management Plan (SMP)

NCST-SDP-FM002
Version 0.1

14 November 2000

DRAFT

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RECORD OF CHANGES

REVISION LETTER	DATE	TITLE OR BRIEF DESCRIPTION	ENTERED BY
Version 0.1	November 14, 2000	Initial Draft Release	E. Karlin

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1. SCOPE

1.1 Identification

This Software Management Plan (SMP) describes the development of the Ground Software (GSW) Computer Software Configuration Item (CSCI) for the Full-sky Astrometric Mapping Explorer (FAME) project. This document applies to the FAME ground software being developed by the Naval Research Laboratory (NRL). It does not apply to the flight software (also being developed by NRL) or to the instrument software being developed by Lockheed Martin Missiles and Space (LMMS).

This software management plan describes the major activities, schedules, resources, and milestones for developing the FAME spacecraft ground software. The areas addressed are:

- Software Engineering Management;
- Software Engineering Development;
- Test Engineering;
- Software Quality Assurance (SQA);
- Software Configuration Management (SCM);
- Software Support;
- Operations Support.

This document is being delivered at the FAME System Requirements Review (SRR) and is essentially complete and final. Updates to this document will be made as needed and will be delivered at subsequent project reviews.

1.2 System Overview

FAME will measure the positions, proper motions, parallaxes, and four-color magnitudes of 40 million stars brighter than 15th visual magnitude during the observational program. The positional accuracy will be the finest yet achieved. The positional, parallax, and proper motion accuracies will be better than 50 μ as, 50 μ as, and 50 μ as/year, respectively for brighter stars.

The FAME Ground Software CSCI consists of all the software required to support the following systems:

- Software Only Test Bed (SOTB);
- Software Test Bed (STB);
- Flight Controller Electrical Aerospace Ground Equipment [a.k.a. Controller Test Bed – (CTB)];
- Electrical Aerospace Ground Equipment (EAGE);
- Electrical Launch Support Equipment (ELSE);
- Satellite Simulator (SATSIM);
- Mission Operations Center (MOC);
- Science Operations Center (SOC).

Each of these systems utilizes the OS/COMET ground software toolkit as the core infrastructure for sending commands and processing telemetry. The application software built on top of the OS/COMET toolkit provides the mission-specific software for each of these systems. From a software viewpoint, these systems perform many of the same functions, and therefore, the ground software is managed as a single CSCI.

1.3 Document Overview

This plan identifies and describes the management, development, and verification for the FAME Ground Software CSCI. It serves as a source document for the quality control, configuration management (CM), and defect tracking for the development of the ground software. This plan documents the results of the planning process performed by the software development manager for development activities for the FAME ground software. The sections of this document and their specific purposes are listed below:

- Section 1.0, Scope, provides the identification and overview of this document as well as the system and software to be developed;
- Section 2.0, Applicable Documents, lists the documents referenced in this plan or that are applicable to the software development products or processes;

- Section 3.0, Software Engineering Management, describes the overall project management approach including the project organization, resources, work breakdown structure, schedule, and deliverables;
- Section 4.0, Software Engineering Development, describes the software development approach including architecture, life cycle model, detailed activities, and unit level testing;
- Section 5.0, Test Engineering, describes the software testing approach;
- Section 6.0, Software Quality Assurance, describes the plan for quality assurance of the software and related documents;
- Section 7.0, Software Configuration Management, describes the plan for configuration control of software and related documents;
- Section 8.0, Software Support, describes the software development environment and data-handling plan;
- Section 9.0, Operations Support, describes the plan for providing operations support of the delivered software;
- Section 10, Notes, provides a list of the acronyms and abbreviations used in this document.

1.4 Relationship to Other Plans

This Software Management Plan is consistent with both the FAME Project Management Plan (NCST-D-FM003) and the FAME Configuration Management Plan (NCST-D-FM009). Certain sections of the FAME Flight Software Management Plan (NCST-SDP-FM001) that also apply to the ground software are incorporated into this plan by reference.

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2.APPLICABLE DOCUMENTS

This section lists documents that either are referenced in this Software Management Plan or provide additional information applicable to the understanding of this document.

2.1 Government Documents

2.1.1 NRL Documents

The following documents are FAME project specific:

Table 2-1. NRL Documents

Document Number	Document Title
NCST-D-FM001	Science Requirements Document for the Full-sky Astrometric Mapping Explorer (FAME)
NCST-D-FM002	Mission Requirements Document for the Full-sky Astrometric Mapping Explorer (FAME)
NCST-D-FM003	Project Management Plan for the for the Full-sky Astrometric Mapping Explorer (FAME)
NCST-D-FM004	Systems Engineering Management Plan (SEMP) for the Full-sky Astrometric Mapping Explorer (FAME)
NCST-D-FM008	Configuration Management Plan (CMP) for the Full-sky Astrometric Mapping Explorer (FAME)
NCST-SDP-FM001	FAME Flight Software Management Plan (SMP)
NCST-ICD-FM003	Space to Ground ICD for the Full-sky Astrometric Mapping Explorer (FAME)

2.1.2 Military and International Standards

The FAME Ground Software CSCI uses the following military standards (MIL-STD) and international standards:

Table 2-2. Military/International Standards

Document Number	Document Title
MIL-STD-498	Software Development and Documentation, 5 December 1994
ISO/IEC 12207	Information Technology – Software Life Cycle Processes, August 1995
ISO/IEC 9899	ANSI C Standard Programming Language

2.2 Non-Government Documents

2.2.1 Commercial Documents

The following commercial documents provide additional information on commercial off-the-shelf (COTS) software:

Table 2-3. Commercial Documents

Vendor	Document Title
Wind River Systems	VxWorks Programmer's Guide
Wind River Systems	VxWorks Reference Manual
Wind River System	VxWorks User's Manual
Rational	ClearCase/ClearQuest Administrator's Manual
Rational	ClearCase/ClearQuest User's Manual

3.SOFTWARE ENGINEERING MANAGEMENT

This section of the Software Management Plan addresses the software engineering management approach used by the NRL to manage the development of the FAME ground software.

3.1 Project Organization

The NRL is responsible for development of the spacecraft bus hardware, flight software, and ground data systems for the FAME project. Figure 3-1 depicts the NRL organization for the FAME project as it relates to the software development effort.

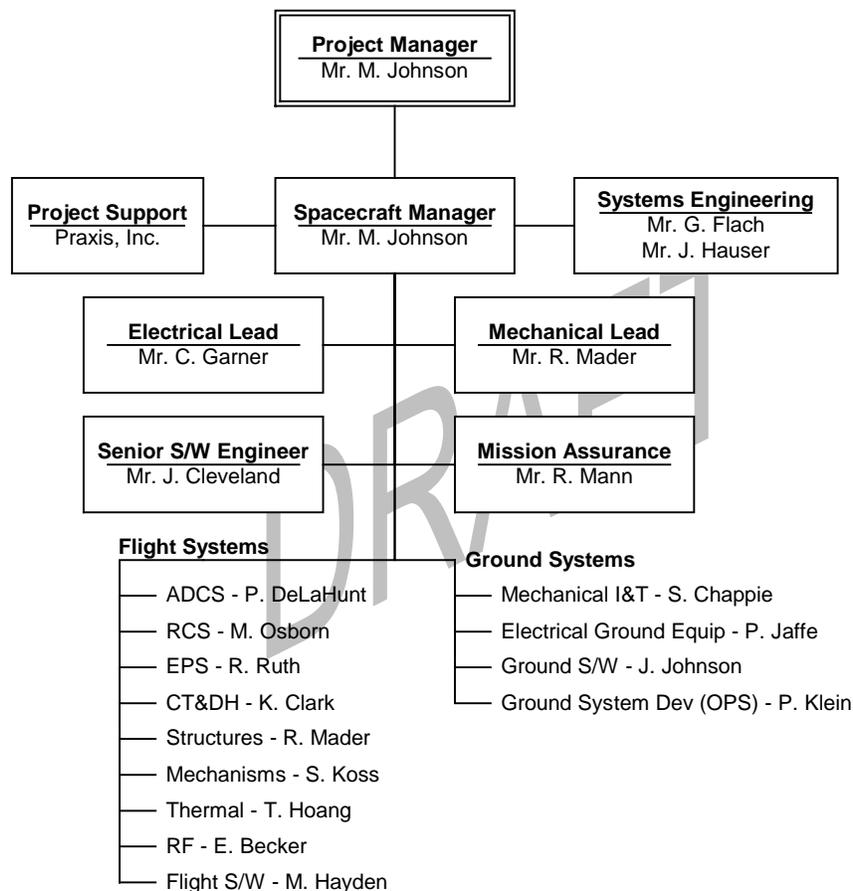


Figure 3-1. FAME Project Organization for Software-related Areas

3.2 Roles and Responsibilities

The ground software for the FAME project is being developed within the NRL NCST Electrical Systems Segment. The key individuals and their areas of responsibility are listed below:

- C. Garner is the Segment Manager responsible for the Electrical Systems Segment;
- J. Johnson is the Subsystem Manager responsible for ground software. This encompasses the following software systems:
 - Software Only Test Bed (SOTB),
 - Software Test Bed (STB),
 - Flight Controller Electrical Aerospace Ground Equipment [Controller Test Bed – (CTB)],
 - Electrical Aerospace Ground Equipment (EAGE),
 - Electrical Launch Support Equipment (ELSE),

- Satellite Simulator (SATSIM);
- P. Klein is the Subsystem Manager responsible for the operational ground system development. This encompasses the following software systems:
 - Mission Operations Center (MOC),
 - Science Operations Center (SOC).

3.2.1 FAME Software Development Organizations

Figure 3-2 details the structure of the FAME ground software development management team.

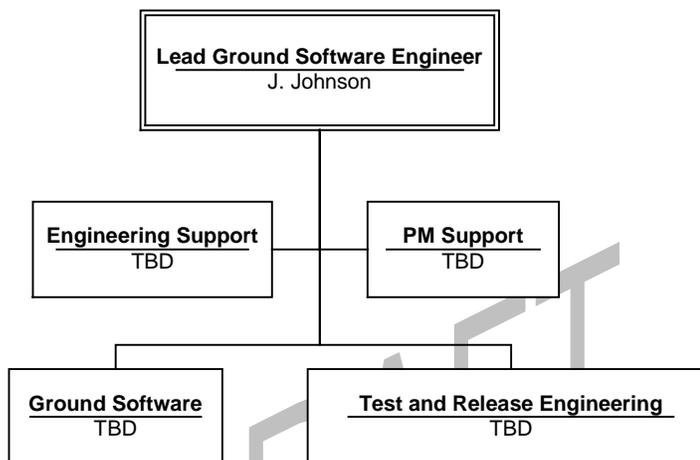


Figure 3-2. Ground Software Organization

In order to gain independence in the software development and testing activities, the FAME ground software development and testing responsibilities are partitioned into independent groups within the NRL. This provides an independent verification of the FAME ground software. Table 3-1 provides a description of the responsibilities of each of these groups.

Table 3-1. Software Groups

Software Group	Responsibility
Ground Software Group	Responsible for the development of the ground software that executes in various test bed configurations as well as the MOC and SOC.
Test and Release Engineering Group	Responsible for the development of the Software Test Descriptions (NCST-STD-FM002) and Software Test Report (NCST-STR-FM002) documents for verification of the FAME ground software operating in the MOC and SOC. This group will develop the ground software test procedures and descriptions, and perform the ground software qualification testing for the MOC and SOC. This group will also provide Configuration Management (CM) services to the Ground Software group. The CM services include version and baseline control during development and providing releases for both qualification testing and ground operations.

3.3 Work Breakdown Structure (WBS)

The software functions are partitioned into the various software/systems engineering. Table 3-2 presents the Work Breakdown Structure (WBS) based on these disciplines, the WBS Products, and the Responsible Individual (RI).

Table 3-2. Work Breakdown Structure

WBS	WBS Name	WBS Products	RI
1.1	Software Management	Ground Software Management Plan (SMP)	J. Johnson
1.2	Systems/Software Engineering	System Requirements Review (SRR) Inputs Ground Software Requirements Specification (SRS) System Preliminary Design Review (PDR) Inputs System Critical Design Review (CDR) Inputs	J. Johnson
1.3	Software Engineering	Ground Software Design Presentations Ground Software User Manual (SUM) Ground Software Builds Software Version Descriptions (SVDs)	TBD
1.4	Test Engineering	Ground Software Test Descriptions (STDs) Ground Software Test Reports (STRs)	TBD
1.5	Software Support	Software QA (defect tracking, change management) Ground Software Releases	TBD

3.4 Master Schedule

The high-level schedule for the ground software development efforts is maintained at the FAME project level. This schedule is updated at least monthly to reflect in-progress and completion status along with current milestone dates. The high-level schedule tracks timelines for ground software development and ground software documentation.

The high-level software development schedule tracks the software development progress using build, qualification test, and release milestones. Details regarding the most recent project schedule status are available from Mr. Mark Johnson, Project Manager, who may be reached at the NRL FAME Project Office. This detailed schedule will map components and requirements to the build milestones.

Table 3-3 identifies the key functionality to be provided in each of the ground software releases. Ground software releases will be coordinated with associated flight software releases. The ground software functionality for each build is driven partially by the flight software functionality being tested in each of the corresponding flight software builds. The ground software build functionality is also driven by the specific ground support equipment that must be controlled for each test bed or operational environment that must be supported by the build.

Table 3-3. Ground Software Release Descriptions

Release	Description
Build 1.0	C&T database development Basic telemetry processing Basic command processing Basic equipment control SOTB/STB/CTB support
Build 2.0	Telemetry playback Command verification Command history Memory processing EAGE/SATSIM support
Build 3.0	Complete telemetry processing Complete command processing ELSE support
Build 4.0	Operational scripts and displays MOC/SOC support

3.5 Deliverables

3.5.1 Software

The FAME Ground Software (GSW) Computer Software Configuration Item (CSCI) is partitioned into a group of software components whose interactions compose the software architecture. The software architecture for the GSW CSCI is primarily defined by the OS/COMET COTS product that provides the infrastructure for the ground software. FAME application specific software architecture is documented in the FAME Ground Software User Manual, NCST-SUM-FM002.

The FAME Ground Software CSCI software components will be managed using the Rational ClearCase/Multi-site/ClearQuest CM tool set. Source code will be delivered for all NRL-developed software components. All build procedures, utilities, test databases and test procedures will be delivered to support building of the software components for system integration and test, operations and maintenance. All compiled source code object files, object libraries and executables are also delivered.

3.5.2 Documentation

The FAME Ground Software CSCI document set addresses the areas of Project Management, System/Software Engineering, Test Engineering, Release Support, and Product Use. Table 3-4 lists the deliverable FAME ground software documents. Subsection 3.5.2.1 provides a description of each document.

Table 3-4. FAME Documentation Deliverables

Document Number	Deliverable Product
NCST-SDP-FM002	FAME Ground Software Management Plan
NCST-SRS-FM002	FAME Ground Software Requirements Specification
NCST-STD-FM002	FAME Ground Software Test Description
NCST-STR-FM002	FAME Ground Software Test Report
NCST-SVD-FM002	FAME Ground Software Version Description
NCST-SUM-FM002	FAME Ground Software User Manual

3.5.2.1 Deliverable Document Descriptions

The following describes the deliverable documentation set for the FAME Ground Software CSCI. All documents will remain current as requirements or the design changes. For each version of the CSCI, any updated documents will be released as a new version. The Software Version Description (SVD) will identify the documents related to the software build.

3.5.2.1.1 FAME Software Management Plan, NCST-SDP-FM002

This SMP establishes the approach for the development of the FAME Ground Software CSCI. It describes the software organizational framework, software management, deliverables, software development activities, software integration and test activities, software quality assurance (SQA), CM, software support, and operations support.

3.5.2.1.2 FAME Ground Software Requirements Specification, NCST-SRS-FM002

The Ground Software Requirements Specification (SRS) establishes the functional and performance requirements for the FAME Ground Software CSCI. The Ground SRS will be used as the basis for performing the ground software design and the ground software qualification testing for the MOC/SOC.

3.5.2.1.3 FAME Ground Software Test Description, SDD-STD-FM002

The Ground Software Test Description (STD) document establishes the test environment, test approach, test cases, test descriptions, test procedures, and expected test results for software qualification testing of the FAME Ground Software for the MOC/SOC. The STD will trace the ground software requirements to the test cases. The test case

descriptions will give all of the detailed information associated with the actual test. The automated test procedures and associated data files that implement the test descriptions will be referenced in an appendix to the STD. The STD will conform to the FAME tailoring of MIL-STD-498 as identified in DID DI-IPSC-81439 found in appendix C of the FAME Flight Software Management Plan (NCST-SDP-FM001).

3.5.2.1.4 FAME Ground Software Test Report, NCST-STR-FM002

The Ground Software Test Report (STR) documents the results of the execution of the ground software automated test procedures. The Ground STR documents the actual results vs. the expected results, problems encountered during testing, deviations from test case procedures, and test evaluations/recommendations. The STR will conform to the FAME tailoring of MIL-STD-498 as identified in DID DI-IPSC-81440 found in appendix C of the FAME Flight Software Management Plan (NCST-SDP-FM001).

3.5.2.1.5 FAME Ground Software Version Description, NCST-SVD-FM002

A Ground Software Version Description (SVD) will be produced for each release of the FAME Ground Software. The Ground SVD identifies the ground software release for the FAME system. The SVD identifies, at a minimum, the software components being delivered, resolved Ground Software Action Requests (GSWARs), and any known deficiencies. The SVD will also define the configuration of all tools and data sets used to generate the version. The SVD is prepared by CM and released with the deliverable software product. The SVD will conform to the FAME tailoring of MIL-STD-498 as identified in DID DI-IPSC-81442 found in appendix C of the FAME Flight Software Management Plan (NCST-SDP-FM001).

3.5.2.1.6 FAME Ground Software User Manual, NCST-SUM-FM002

A Ground Software User Manual (SUM) will be produced for each release of the FAME Ground Software. The Ground SUM describes the ground software architecture as dictated primarily by the OS/COMET COTS command and control toolkit and extended by application specific components. The SUM will identify and describe each file included in the ground software and will provide software operation descriptions and examples.

3.5.2.2 Project Document Formats

The FAME project documents will be created and managed using Microsoft Office 2000 tools (Word, Excel, PowerPoint, Access, Visio) on Windows 98/Windows NT platforms. Released documents will be available electronically in Portable Document Format (PDF) in Adobe Acrobat.

3.6 Size Estimates

This subsection describes the software estimation process employed by NRL in developing size, effort, and cost estimates for the FAME software. The basis for the estimates is historical information from previous projects.

3.6.1 Software Size Estimates

Ground software estimates are based on the software size for the ICM project. Table 3-5 shows the projected ground software size estimates:

Table 3-5. Ground Software Size Estimates

Component	LOC	Reuse
Control System Services	475,000	465,000
Command and Telemetry	18,000	3,000
Ground Support Equipment Control	20,000	6,000
Modeling and Simulation	10,000	0
System Test	17,000	2,000
Operations Support	7,000	2,000
Total	547,000	478,000

3.7 Project Resources

3.7.1 Personnel

Table 3-6 shows the staffing projections by software group over a projected three (3)-year period of performance.

Table 3-6. Staffing Projection by Software Group

WBS/Staff	Ground Software	Test and Release	Total
Software Management	0.5	0.2	0.7
Software/System Engineering	1.0	1.0	2.0
Software Development Engineering	2.5	0.0	2.5
Software Test Engineering	0.0	1.0	1.0
Quality Assurance	0.0	0.5	0.5
Configuration Management	0.0	0.5	0.5
Software Support	0.0	0.5	0.5
Totals	4.0	3.7	7.7

3.8 Project Budgets

The project budgets are based on the man loading, planned travel, and equipment purchases to support software development as well as integration and test. The FAME budgets are maintained separately by the FAME Project Manager and are not included in this SMP.

3.9 Project Management

3.9.1 Project Planning/Monitoring

This SMP is the primary planning document for the FAME Ground Software CSCI. Detailed schedules will be developed and progress will be monitored using monthly status reports.

3.9.2 Risk Management

Risks will be managed throughout the FAME ground software development effort. The Lead GSW Engineer will identify risks. Status reports and Software Review Board (SRB) issues will both be used as the means for risk documentation, notification and tracking. This information will be elevated to FAME project management for review. The following information will be used to describe each identified risk:

- Risk Area identifies the area of risk;
- Risk Type identifies the engineering group affected;
- Risk Mitigation Strategy identifies control/reduction strategy for the risk.

3.9.3 Reviews and Reports

3.9.3.1 Management Reviews and Reports

Internal software reviews will be held on a monthly basis (or as necessary) to review the overall software status. These meetings will be held to review the software schedule, cost, priorities, and issues/concerns.

Status reports will also be submitted monthly and will include an updated software schedule, accomplishments for the previous month, plans for the next month, and any issues/concerns.

3.9.3.2 Technical Reviews and Reports

3.9.3.2.1 Technical Reviews

Several technical reviews are planned during the FAME project. The reviews with related ground software tasks are listed in the subsections below.

In addition to these activities, all deliverable software documents will be made available for review in draft form prior to the first official release of the documents. Once the document is officially released, a Review Item Discrepancy (RID) or Configuration Control Notice (CCN) must be completed to request a change to a software document.

3.9.3.2.1.1 System Requirements Review (SRR)

Review the overall system requirements including expected reuse. The FAME Ground Software Management Plan (NCST-SDP-FM002) will be released.

3.9.3.2.1.2 Preliminary Design Review (PDR)

Review the preliminary system design. Initial versions of the FAME Ground Software Requirements Specification (NCST-SRS-FM002) and the FAME Ground Software Test Description (NCST-STD-FM002) will be released following PDR.

3.9.3.2.1.3 Critical Design Review (CDR)

Review the detailed system design. The initial release of the FAME Ground Software User Manual (NCST-SUM-FM002) follows CDR.

3.9.3.2.1.4 Test Readiness Review (TRR)

Review of readiness to begin formal FAME ground data system level testing for the MOC/SOC environments. The FAME Ground Software Requirements Specification (NCST-SRS-FM002), the FAME Ground Software Test Description (NCST-STD-FM002), and the FAME Ground Software Version Description (NCST-STD-FM002) will be released, under document CM and available for review two weeks prior to TRR. Also available for review two weeks prior to TRR will be the GSW source code as built for Software Qualification Testing, a list of all outstanding work with a closure plan and schedule, the Ground Software Requirement Compliance and Verification worksheets, and an initial draft version of the FAME Ground Software Test Report (NCST-STR-FM002).

3.9.3.2.2 Technical Peer Reviews

In addition to the formal technical reviews, several technical peer reviews are planned. These include:

- Peer reviews of software requirements analysis artifacts;
- Peer reviews of software architectural and detailed design;
- Peer inspections of software unit implementation;
- Peer reviews of software integration.

These reviews are detailed individually in Subsection 4.3.

3.9.3.2.3 Technical Interchange Memos

Technical Interchange Memos (TIMs) will be used as the mechanism to address technical issues that are relevant to agencies external to NRL.

3.9.3.2.4 Technical Notes

TNs will be written as required to document technical approaches and design. These are primarily for internal purposes and provide rationale for a particular software approach or design. Additional notes related to the development of a particular software component are informally documented in the FAME Ground Software Design Presentation (i.e. PowerPoint slides).

3.9.3.2.5 Ground Software Action Requests (GSWARs)

GSWARs are the mechanism to be used to request a ground software change and/or report a ground software deficiency. All GSWARs will be tracked via the FAME CM system. A library of documentation, memos, and notes will be provided for linking and tracking technical details concerning GSWARs.

3.9.3.2.6 Software Review Board

The Software Review Board (SRB) will be used as the forum to present all proposed changes to the FAME Ground Software. The SRB members will include the Lead GSW Engineer and the Lead FSW Engineer. The SRB will review and disposition all changes to the GSW and associated external interfaces. The SRB will be formed when the GSW and interfaces have matured to the extent that the GSW development is complete and the external interfaces are stable. The Lead GSW engineer will determine when the SRB activities are initiated. Proposed GSW changes will be dispositioned by the board members unless technical or cost issues require FAME Project Management (PM) and/or FAME System Engineering (SE) review. SRB issues that require FAME PM/SE review will be presented at the FAME monthly software status meeting.

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4. SOFTWARE ENGINEERING DEVELOPMENT

4.1 Software Life Cycle

The FAME Ground Software development effort will utilize an incremental software life cycle model. The incremental development model calls for a series of development builds, each of which leads to a product to be used in a test environment until the next incremental build is scheduled. Each incremental build provides more of the functionality required until the full functionality of the product is attained. Each incremental build in this model represents a development cycle including the activities of detailed design, code and unit test, and integration. The incremental software builds that have been identified for the FAME development effort are documented in Table 3-3, Ground Software Release Descriptions. The GSW versions intended for operational use in the Mission Operations Center (MOC) and the Science Operations Center (SOC) will undergo qualification testing to ensure requirement compliance and operational capabilities.

4.2 Software Engineering Methodology

4.2.1 Software Development Methods

The FAME Ground Software will be designed using Structured Analysis and Design. The method employed is a well-defined approach to developing software where the software system is partitioned into components and interfaces between them are defined in terms of data flows or control flows. Components are then partitioned into software units. Example tools for the method include data/control flow diagrams for analysis and architectural (top-level) design, and traditional programming structure diagrams to document function calling trees for detailed design.

Components of the OS/COMET COTS ground software toolkit will be utilized to implement the core control system infrastructure for the ground software deployed on Sun Workstations. Because most of the ground software developed on these workstations will be a layer on top of OS/COMET, many architectural and detailed design decisions for this ground software will be dictated by the COTS product.

Other parts of the ground software will be deployed on VME-based front-end processors (FEPs) and will not be built using OS/COMET. This ground software will not be constrained by the mechanisms of OS/COMET although there will be interfaces to OS/COMET-based applications running on the Sun Workstations.

4.2.2 Software Development Terminology

The terms 'software architecture,' 'software component,' 'software unit,' 'review,' and 'inspection' are used throughout the sections that follow. The following subsections define these terms as used in this document.

4.2.2.1 Software Architecture

The software architecture is the top-level design of the software system that defines the high-level structure and identifies the software components. It describes all external interfaces, the software components, and the connection or internal interface between the software components.

4.2.2.2 Software Component

A software component is defined as the partitioning and sub-partitioning of the software system into high-level functional areas, software tasks (i.e. Unix processes), or shared software libraries.

4.2.2.3 Software Units

A software unit is a separately compilable subdivision of a software component that provides a well-defined service of the component. A software unit has a well-defined interface for providing the service. A software unit may be implemented via a combination of both external functions (interface) and internal functions. All software units will be traceable to one (1) software component.

4.2.2.4 Review

A review is the examination of a work product to determine whether the product has met its requirements and acceptance criteria. The participants and level of detail in the review will vary depending on the work product under review.

4.2.2.5 Inspection

An inspection is the detailed examination of a software unit. The inspection will determine if the unit satisfies all requirements, and that all design, coding and unit test standards have been met. In addition, the unit software source code will be checked for defects in implementation of the component design.

4.2.3 Software Standards

The ground software that is developed for FAME (not COTS or NDI) and is not constrained by third-party tools such as OS/COMET will adhere to the software standards specified in the FAME Flight Software Management Plan (NCST-SDP-FM001). These software standards are applied to all activities as a driving force during development and as a quality check during the review after each activity.

4.2.4 Software Reuse

The FAME Ground Software will utilize a combination of Commercial Off-The-Shelf (COTS) software and software components from previous projects at the Naval Research Laboratory (NRL). Components from the NASA Integrated Test and Operations System (ITOS) Government Off-The-Shelf (GOTS) software product will also be reused, although it is possible that only design information for some of these components can be applied.

4.2.4.1 Commercial Off-The Shelf (COTS) Software

Various COTS products will be used to support the FAME Ground Software. The following list details some of the significant operational COTS products:

- VxWorks Real-Time Operating System will be used on the VME-based Front-End Processors (FEPs);
- OS/COMET ground system toolkit will be used for core Command and Telemetry (C&T) capabilities on the Sun Workstations.

4.2.4.2 Non-Developmental Item (NDI)

Software components will be reused as appropriate during both design and coding. The determination of specific component reusability will occur during the architectural design, detailed design, and coding phases of software development.

The NDI software planned for reuse for the FAME Ground Software includes the BP Generic Front-End Processor component and various components of the NASA ITOS product such as the CCSDS Telemetry/Telecommand recommendation implementations and the remote telemetry monitoring component. Although direct code reuse is preferred, in some cases only design information will be applicable for reuse and code will have to be modified or mostly re-engineered.

4.3 Software Development Activities

This section details the software development activities to be performed during FAME Ground Software development. Each subsection details an activity of the software process to be used by NRL in management and development of the ground software. Using the incremental software life cycle model, iterations will occur across the various activities for each software release.

4.3.1 Software Requirements Analysis

The Software Requirements Analysis activity identifies specific CSCI software requirements and interfaces from the baselined system documents.

4.3.1.1 Resources

The resources required for the Software Requirements Analysis activity are the FAME documents and packages listed below:

- FAME Mission Requirements Document, (NCST-D-FM002);
- FAME Ground Software Management Plan, (NCST-SDP-FM002);
- FAME System Requirements Review (SRR) and Preliminary Design Review (PDR) Presentation Packages.

4.3.1.2 Work Products

The work products for the Software Requirements Analysis activity are listed below:

- FAME Ground Software Requirements Specification, (NCST-SRS-FM002);
- FAME Space to Ground ICD (NCST-ICD-FM003), generated jointly by the flight and ground software teams.

4.3.1.3 Reviews

During the Software Requirements Analysis activity, a peer review of the FAME Ground SRS and the FAME Space to Ground ICD will be performed with the ground software group and the flight software lead engineer. The review team will evaluate the software requirements with respect to the criteria listed below:

- Traceability to system requirements and system design;
- External consistency with system requirements;
- Internal consistency;
- Testability;
- Feasibility of software design;
- Feasibility of operation and maintenance.

4.3.1.4 Exit Criteria

The exit criteria for the Software Requirements Analysis activity are listed below:

- All action items identified in the Ground SRS peer review shall be resolved, and the Ground SRS entered into CM;
- All action items identified in the Space to Ground ICD peer review shall be resolved, and the Space to Ground ICD entered into CM.

4.3.2 Software Architectural Design

During the Software Architectural Design activity, the top-level CSCI component structure is developed. The software requirements identified in the SRS are allocated to the identified software components. The interfaces external to the CSCI and between components of the CSCI are defined.

4.3.2.1 Resources

The resources required for the Software Architectural Design activity are the FAME documents and packages listed below:

- FAME Mission Requirements Document, (NCST-D-FM002);
- FAME Ground Software Management Plan, (NCST-SDP-FM002);

- FAME System Requirements Review (SRR) and Preliminary Design Review (PDR) Presentation Packages;
- FAME Ground Software Requirements Specification, (NCST-SRS-FM002);
- FAME Space to Ground ICD (NCST-ICD-FM003).

4.3.2.2 Work Products

The work products for the Software Architectural Design activity are listed below:

- FAME Ground Software Design Presentation documenting the architectural design, containing at a minimum:
 - Identification of all Computer Software Components (CSCs),
 - Allocation of SRS Requirements to Components,
 - Ground Software External and Internal Interfaces;
 - Refined FAME Space to Ground ICD (NCST-ICD-FM003), updated jointly by the flight and ground software teams;
 - Draft FAME Ground Software User Manual (NCST-SUM-FM002);
 - Draft FAME Ground Software Test Description (NCST-STD-FM002).

4.3.2.3 Reviews

During the Software Architectural Design activity, a peer review of the top-level CSCI design using the FAME Ground Software Design Presentation will be held to review the software component structure, requirements allocation, and interface definitions. Refinements to the Space to Ground ICD will also be examined in a peer review. The review teams will evaluate the software architectural design with respect to the criteria listed below:

- Traceability to the requirements of the CSCI;
- External consistency with the requirements of the CSCI;
- Internal consistency between the software components;
- Appropriateness of design methods and standards used;
- Feasibility of detailed design;
- Feasibility of operation and maintenance.

4.3.2.4 Exit Criteria

The exit criteria for the Software Architectural Design activity are listed below:

- All action items identified in the architectural design peer review shall be resolved, and the FAME Ground Software Design Presentation entered into CM;
- All action items identified in the Space to Ground ICD peer review shall be resolved, and the refined Space to Ground ICD entered into CM.

4.3.3 Software Detailed Design

The Software Detailed Design activity develops the internal structure of each software component of the CSCI. Each component is decomposed into one or more software units that can be coded, compiled, and tested. The software requirements are allocated from the software components to the software units. The unit design captures the unit interfaces and the detailed descriptions of the unit.

4.3.3.1 Resources

The resources required for the Software Detailed Design activity are the FAME documents and packages listed below:

- FAME Mission Requirements Document, (NCST-D-FM002);
- FAME Ground Software Management Plan, (NCST-SDP-FM002);
- FAME Ground Software Requirements Specification, (NCST-SRS-FM002);
- FAME Space to Ground ICD (NCST-ICD-FM003);

- FAME Critical Design Review (CDR) Presentation Package;
- FAME Ground Software Design Presentation.

4.3.3.2 Work Products

The work products for the Software Detailed Design activity are listed below:

- Refined FAME Ground Software Design Presentation, containing at a minimum:
 - Identification of all the Units within the Components of the CSCI,
 - Unit Interfaces,
 - Unit Descriptions;
 - Refined FAME Space to Ground ICD (NCST-ICD-FM003), updated jointly by the flight and ground software teams;
 - Refined FAME Ground Software User Manual (NCST-SUM-FM002);
 - Refined FAME Ground Software Test Description (NCST-STD-FM002).

4.3.3.3 Reviews

During the Software Detailed Design activity, a peer review of the low-level design using the FAME Ground Software Design Presentation will be held to review the software unit design. Refinements to the Space to Ground ICD will also be examined in a peer review. The review teams will evaluate the software detailed design with respect to the criteria listed below:

- Traceability to the requirements of the CSCI;
- External consistency with architectural design;
- Internal consistency between the software components and software units;
- Appropriateness of design methods and standards used;
- Feasibility of testing;
- Feasibility of operation and maintenance.

4.3.3.4 Exit Criteria

The exit criteria for the Software Detailed Design activity are listed below:

- All action items identified in the detailed design peer review shall be resolved, and the refined FAME Ground Software Design Presentation entered into CM;
- All action items identified in the Space to Ground ICD peer review shall be resolved, and the refined Space to Ground ICD entered into CM.

4.3.4 Software Coding and Unit Testing

The Software Coding and Unit Testing activity implements each software unit. The source code for each development software unit is written and unit level testing is accomplished. The unit test approach will be based on the developer's judgement and experience. Unit testing will utilize a combination of manual and automated procedures.

4.3.4.1 Resources

The resources required for the Software Coding and Unit Testing activity are the FAME documents and packages listed below:

- FAME Mission Requirements Document, (NCST-D-FM002);
- FAME Ground Software Management Plan, (NCST-SDP-FM002);
- FAME Ground Software Requirements Specification, (NCST-SRS-FM002);
- FAME Space to Ground ICD (NCST-ICD-FM003);
- FAME Critical Design Review (CDR) Presentation Package;
- FAME Ground Software Design Presentation.

4.3.4.2 Work Products

The work products for the Software Coding and Unit Testing activity are listed below:

- Source code for each software unit;
- Unit test descriptions, unit test procedures, unit test data and unit test results for a subset of units (determined by lead ground software engineer);
- Refined FAME Ground Software Design Presentation;
- Refined FAME Ground Software User Manual (NCST-SUM-FM002);
- Refined FAME Ground Software Test Description (NCST-STD-FM002).

4.3.4.3 Reviews

During the Software Coding and Unit Testing activity, inspections will be held to review the source code and unit test documentation for a subset of units (subset is determined by lead ground software engineer). Refinements to the FAME Ground Software Design Presentation and the FAME Ground Software User Manual will also be examined in peer reviews. The review teams will evaluate the software coding and unit testing with respect to the criteria listed below:

- Traceability to the requirements and design of the CSCI;
- External consistency with the requirements and design of the software;
- Internal consistency between unit requirements;
- Test coverage of units;
- Appropriateness of coding methods and standards used;
- Feasibility of software integration and testing;
- Feasibility of operation and maintenance.

4.3.4.4 Exit Criteria

The exit criteria for the Software Coding and Unit Testing activity are listed below:

- All action items identified by the inspections shall be resolved, and the source code, unit test descriptions, unit test procedures, unit test data and unit test results entered into CM;
- All action items identified in the FAME Ground Software Design Presentation peer review shall be resolved, and the refined presentation entered into CM;
- All action items identified in the FAME Ground Software User Manual peer review shall be resolved, and the refined manual entered into CM.

4.3.5 Software Integration

The Software Integration activity combines the software units and software components into aggregates until the entire CSCI is integrated. Informal testing is performed as the aggregates are developed to ensure each aggregate satisfies the requirements of the CSCI and the CSCI is successfully integrated at the conclusion of the integration activity. For each qualification requirement of the CSCI, a set of test cases, test procedures, and test data is developed for conducting software qualification testing. The test procedures will contain the expected results of each test.

4.3.5.1 Resources

The resources required for the Software Integration activity are the FAME documents and packages listed below:

- FAME Mission Requirements Document, (NCST-D-FM002);
- FAME Ground Software Management Plan, (NCST-SDP-FM002);
- FAME Ground Software Requirements Specification, (NCST-SRS-FM002);
- FAME Space to Ground ICD (NCST-ICD-FM003);
- FAME Critical Design Review (CDR) Presentation Package;
- FAME Ground Software Design Presentation;
- FAME Ground Software User Manual (NCST-SUM-FM002);

- FAME Ground Software Test Description (NCST-STD-FM002).

4.3.5.2 Work Products

The work products for the Software Integration activity are listed below:

- Updated source code for each software unit in the integrated CSCI;
- Binary object files, libraries, databases, and executables for the integrated CSCI;
- Refined FAME Ground Software Test Description (NCST-STD-FM002) containing test cases, test procedures, test data, and expected results;
- Draft FAME Ground Software Test Report (NCST-STR-FM002);
- Draft FAME Ground Software Version Description (NCST-SVD-FM002).

4.3.5.3 Review

A peer review will be held to review the Software Integration activity. Refinements to the FAME Ground Software Test Description will also be examined in a peer review. The review team will evaluate the software integration with respect to the criteria listed below:

- Traceability to the system requirements;
- External consistency with the system requirements;
- Internal consistency;
- Test coverage of the requirements of the CSCI;
- Appropriateness of test methods and standards used;
- Conformance of expected results;
- Feasibility of software qualification testing;
- Feasibility of operation and maintenance.

4.3.5.4 Exit Criteria

The exit criteria for the Software Integration activity are listed below:

- All action items identified in the CSCI integration peer reviews shall be resolved, and the source files and binary files of the integrated CSCI entered into CM;
- All action items identified in the FAME Ground Software Test Description peer review shall be resolved, and the document entered into CM.

4.3.6 Software Qualification Testing

The Software Qualification Testing activity verifies the integrated CSCI satisfies the qualification requirements documented in the SRS. The requirement compliance activities will include the test, inspection, analysis and demonstration actions as identified in the SRS. The results of these activities will be captured in the FAME Ground Software Test Report.

4.3.6.1 Resources

The resources required for the Software Qualification Testing activity are the FAME documents and packages listed below:

- FAME Mission Requirements Document, (NCST-D-FM002);
- FAME Ground Software Management Plan, (NCST-SDP-FM002);
- FAME Ground Software Requirements Specification, (NCST-SRS-FM002);
- FAME Space to Ground ICD (NCST-ICD-FM003);
- FAME Critical Design Review (CDR) Presentation Package;
- FAME Ground Software Design Presentation;
- FAME Ground Software User Manual (NCST-SUM-FM002);
- FAME Ground Software Test Description (NCST-STD-FM002);
- Draft FAME Ground Software Test Results (NCST-STR-FM002).

4.3.6.2 Work Products

The work products for the Software Qualification Testing activity are listed below:

- FAME Ground Software Test Results (NCST-STR-FM002);
- FAME Ground Software Version Description (NCST-SVD-FM002).

4.3.6.3 Reviews

During the Software Qualification Testing activity, a review will be held to review the qualification testing. The review team will evaluate the software qualification testing with respect to the criteria listed below:

- Test coverage of the requirements of the CSCI;
- Conformance to expected results;
- Feasibility of system integration and testing;
- Feasibility of operation and maintenance.

4.3.6.4 Exit Criteria

The exit criteria for the Software Qualification Testing activity are listed below:

- All action items identified in the qualification testing review shall be resolved, and the FAME Ground STR and FAME Ground SVD entered into CM;
- A baseline shall be established in CM for the design, source code, and binary files of the CSCI;
- NRL shall complete the sign-off for the qualification test.

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5. TEST ENGINEERING

Three (3) levels of software testing have been identified for the FAME Ground Software:

- Unit-Level Testing;
- Integration Testing;
- Qualification Testing.

The individual software developers will perform Unit-Level Testing, which is “white box” testing of a component implementation. Unit-Level Testing will exercise paths in the code that may be difficult to exercise during Integration Testing.

The software developer will also perform Integration Testing, which is “black box” testing of the component verifying the unit and component interfaces as well as functional requirements. Integration Testing will verify an individual component prior to integrating it with other components.

Qualification Testing will be performed to verify that the integrated components of the software item satisfy all the requirements in the Ground Software Requirements Specification (SRS) for the specified software build. The Test Engineering Group will perform this testing.

Each of these testing levels is accomplished during the activities of the development process as described in section 4.3, Software Development Activities. Unit-Level Testing is performed during the Software Code and Unit Test activity described in section 4.3.4. Integration Testing is performed during the Software Integration activity described in section 4.3.5. Qualification Testing is accomplished during the Software Qualification activity described in section 4.3.6.

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6.SOFTWARE QUALITY ASSURANCE

Software Quality Assurance (SQA) will be an on-going assessment of the software development products and processes during all phases of the software development life cycle. SQA activities will be inherent in the FAME software development activities via reviews and inspections. The SQA process will enable all software developers to aid in the achievement of the highest quality software.

The SQA tools for the FAME Ground Software will be identical to the SQA tools used for the FAME Flight Software (e.g.ClearQuest) to allow resource sharing. The SQA processes, activities, and tasks for the FAME Ground Software will be analogous to those used for the FAME Flight Software. For example, the Ground Software Action Request (GSWAR) mechanism will be used for FAME Ground Software just as the Flight Software Action Request (FSWAR) mechanism is used for FAME Flight Software. Refer to the FAME Flight Software Management Plan (NCST-SDP-FM001) for details on the relevant SQA processes, activities, tasks, and tools.

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7. SOFTWARE CONFIGURATION MANAGEMENT (SCM)

The Software Configuration Management (SCM) tools used for the FAME Ground Software will be identical to the SCM tools used for the FAME Flight Software (e.g. ClearCase) to allow resource sharing. The SCM processes, activities, and tasks for the FAME Ground Software will be analogous to those used for the FAME Flight Software. Refer to the FAME Flight Software Management Plan (NCST-SDP-FM001) for details on the relevant SCM processes, activities, tasks, and tools.

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8. SOFTWARE SUPPORT

8.1 Software Development Environment

The Software Development Environment will include multiple Sun workstations, IBM compatible personal computers (PCs), an application/Configuration Management (CM) server, commercial μ P boards, and printers networked together on 100mBit local area network (LAN). This development network will be connected to the four (4) test bed LANs and the Naval Research Laboratory's (NRL's) NRLNet via the FAME backbone network.

Figure 8-1 illustrates the planned software development network. During the development phase software simulators and commercial μ Ps running on the engineering workstations will be used to unit test software that will be eventually be run on long lead time hardware.

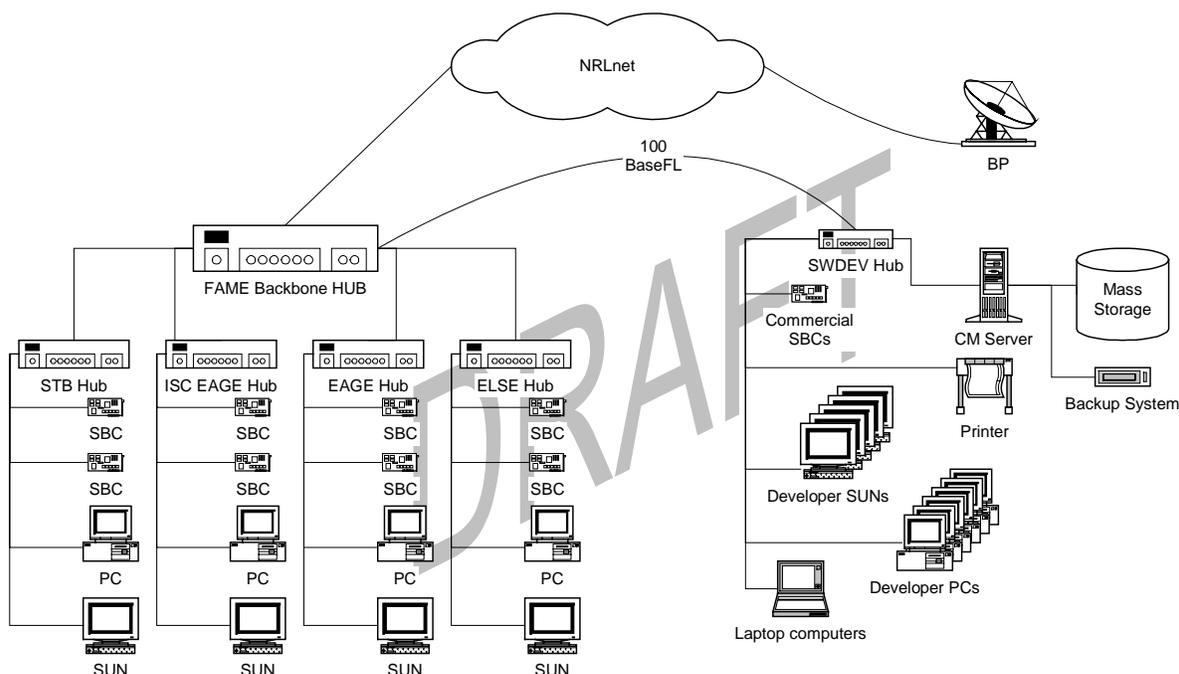


Figure 8-1. Software Development Environment

Table 8-1 details the resources needed for the various phases of development. Software builds will be delivered to the test bed fixtures via the CM tools. This allows changes to be made to software on the test bed that are still under CM. In addition, Ground Software Action Requests (GSWARs) can be submitted directly from the test bed systems. These CM concepts are described in the FAME Software Configuration Management (SCM) Plan.

Table 8-1. Software Development Resources

Project Phase	Product	Qty	Need Date	Description
Development Hardware	Sun Ultra 2	4	2/1/01	Sun Workstations running Solaris 7 operating system, used for the design, coding, and testing of ground software.
	Sun Ultra 60	1	12/1/00	Sun Server used to host CM system, mass storage and system backup hardware
	Pentium PCs	4	2/1/01	PCs running Windows NT used for documentation and as X Terminals to provide additional access to Sun workstations
	Single Board Computers	2	Available	Used to test ground or test bed code.
	SPARCstorage Array Model 112	1	2/1/01	Mass storage for CM system and software. This model supports and will be operated at RAID level 5.
	Printer	2	2/1/01	Provide printing from the development system.
Requirements Analysis	Rational Rose	1	12/1/01	Software requirement analysis and modeling tool.
Ground System Software	OS/COMET™	6	2/1/01	Open Systems / COMmon Environment for Test. Ground system software for command and telemetry tests
	NASA ITOS	1	2/1/01	Integrated Test and Operations System. GOTS software to be reused for CCSDS processing and remote telemetry monitoring.
	SCL™	2	2/1/01	Spacecraft Command Language. Used to provide command/response simulation of FAME spacecraft.
Development	Solaris 7 or greater	4	2/1/01	Open Systems Operating System being used as the primary operating system for FAME development.
	VxWorks cross development environment	2 user	2/1/01	C Development environment for ground code and test bed embedded systems.
	SunSoft Visual Workshop for C	4 user	2/1/01	C & C++ Development Environment for the Sun Workstations.
	SunSoft FORTRAN Workshop Compiler	1 user	2/1/01	FORTRAN development for building Attitude Determination and Control (ADAC) models
Networking	100Base-TX Ethernet Hub	3	2/1/01	Provide fast Ethernet for development system
	10Base-TX Ethernet Hub	1	2/1/01	Provide 10megabit communications for development system
Test / Debugging	WindView and Stethoscope	3	2/1/01	Real-time software characterization and analysis. Will identify and analyze system resource usage, dead-locks, etc.
	VxSim	2	2/1/01	For simulation of embedded systems on the Sun workstations
	Rational Purify	2	2/1/01	Run-time code checking and error detection
	Parasoft Insure++	2 user	2/1/01	Static code checking and error detection
	Rational PureCoverage	2	2/1/01	Testing path coverage
Backup	Sun Solstice	1	2/1/01	Backup software to manage automated backup and tape jukebox
	SPARCstorage 140GB 8mm tape library	1	2/1/01	Tape jukebox for automated system backup
Configuration Management	Rational ClearCase	4	2/1/01	CM System for the organization of both delivered and developed software
Defect Tracking / Requirements Tracking	Rational ClearQuest	4	2/1/01	(Defect Data Tracking System) Software that will aid in requirements tracking by tracking software requirements as defects and relating these requirements to the CM system
	Oracle RDBMS	20 named users	2/1/01	Relational Database Management System. Provides data store for defect data tracking system.
Office Software	MS Office	4	2/1/01	Used for requirements and design database as well as all documentation.

9. OPERATIONS SUPPORT

The ground software development systems will be maintained under Configuration Management (CM) and remain operational for the operational lifetime of the FAME. These systems will be used to continue development of planned ground software releases after the initial operational release.

These systems will also be available to support ground software anomaly resolution, ground software patch development and software patch qualification testing. All software patches and releases will be delivered as qualified and ready for ground operations.

NRL will maintain a staff of ground software developers and support staff as needed to support FAME operations for the duration of the mission. This support will be limited to short intervals of support at BP for critical operations; completion and delivery of ground software versions required after initial operational capability; and anomaly resolution.

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10.NOTES

10.1 Acronyms

<u>Acronym</u>	<u>Definition</u>
API	Application Program Interface
C&T	Command and Telemetry
CCB	Change Control Board
CCN	Configuration Change Notice
CDR	Critical Design Review
CI	Configurable Item
CM	Configuration Management
CMP	Configuration Management Plan
COTS	Commercial Off-The-Shelf
CSC	Computer Software Component
CSCI	Computer Software Configuration Item
DID	Data Item Description
EAGE	Electrical Aerospace Ground Equipment
ELSE	Electrical Launch Support Equipment
FAME	Full-sky Astrometric Mapping Explorer
FDIR	Fault Detection, Isolation, and Recovery
GSW	Ground Software
GSWAR	Ground Software Action Request
FWL	Forward Link
GSW	Ground Software
ICD	Interface Control Document
FAME	Full-sky Astrometric Explorer
ISC	Integrated Spacecraft Controller
LMMS	Lockheed Martin Missiles and Space
LSWE	Lead Software Engineer
MO&DA	Mission Operations and Data Analysis
MRD	Mission Requirements Document
NASA	National Aeronautics and Space Administration
NCST	Naval Center for Space Technology
NDI	Non-Developmental Item
NRL	Naval Research Laboratory
OS/COMET™	Open Systems/Common Environment Test (A proprietary computer language)
PDF	Portable Document Format
PDR	Preliminary Design Review
RI	Responsible Individual
RID	Review Item Discrepancy
RIU	Remote Interface Unit
RTL	Return Link
SCL™	Spacecraft Command Language (A proprietary computer language)
SCM	Software Configuration Management
SCMGR	Software Configuration Manager
SDD	Software Design Document
SDF	Software Development Folder
SEMP	Systems Engineering Management Plan

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<u>Acronym</u>	<u>Definition</u>
SMP	Software Management Plan
SOTB	Software Only Test Bed
SQA	Software Quality Assurance
SRB	Software Review Board
SRR	System Requirements Review
SRS	Software Requirements Specification
STB	Software Test Bed
STD	Software Test Description
STP	Software Test Plan
STR	Software Test Report
SUM	Software User Manual
SVD	Software Version Description
TIM	Technical Interchange Memo
TN	Technical Note
TRR	Test Readiness Review
WBS	Work Breakdown Structure

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