NAVAL RESEARCH LABORATORY

NAVAL CENTER FOR SPACE TECHNOLOGY

System Engineering Management Plan (SEMP)
for the
Full-sky Astrometric Mapping Explorer (FAME)

NCST-D-FM004 **12 December 2000**

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RECORD OF CHANGES

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1. SYSTEM ENGINEERING

The FAME organization employs System Engineering and Integration Team (SEIT) working within the Integrated Product (IPDT) bounds. It is comprised of the lead scientist and engineers for each product area (Instrument, S/C, L/V, GDS, MOC, SOC, Mission Assurance, MO&DA), Science Team Chair, Project Scientist, and a dedicated Systems Engineer. The SEIT integrates project management and systems engineering's technical, cost, and schedule goals, and provides cost-effective identification of conflicting interfaces, requirements, design products, and schedules.

Name	Organization	Responsibility
Ralph Gaume	USNO	MO&DA
Dr. P. K. Seidelman	USNO	SEIT Chairman
Mr. G. Flach	NRL	Systems Engineer
Mr. M. Johnson	NRL	PM, S/C Manager
Mr. R. Mader	NRL	S/C Mechanical Lead
Mr. C. Garner	NRL	S/C Electrical Lead
Dr. R. Vassar	LMMS ATC	Instrument Manager
TBD	SAO	Project Scientist
Dr. S. Horner	LMMS ATC	
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1.1 Requirements Development

The PI together with the Science Team formulates the top-level requirements. These top-level requirements are captured in the Science Requirements Document (SRD), NCST-D-FM001.

1.2 Functional Allocation

From the SRD, the SEIT analyzes needs, objectives, and requirements to determine the functional and performance requirements for each primary mission function and interface.

1.3 Requirements Allocation

Results of the SEIT effort are documented in the Mission Requirements Document (MRD), NCST-D-FM002. The MRD contains specific mission objectives, design criteria for the full range of mission needs, and key referenced documents and/or agreements. It is baselined at SRR and updated at CDR.

1.4 Trade Studies

Major trade studies are defined, conducted and documented during and after the requirements definition phase. Results of such studies provide feedback to functional and requirements allocation as shown in Figure 1.

1.5 Design Optimization and Effective Analysis

The SEIT verifies that engineering products and processes satisfy requirements from the lowest level and that they can be implemented. System level analyses, including performance, reliability, risk; contamination, EMI/EMC, launch vehicle compatibility, and Failure Modes and Effects Analyses (FMEA) will be performed.

1.6 Technical Interface Compatibility

1.7 Synthesis

From the MRD, the traceable design requirements are synthesized to define internal and external interfaces, define system and element solutions to a level that enables verification, identifies critical parameters and translate the architecture into a specification tree, a WBS, specifications, and a configuration baseline.

1.8 Specification Generation

A boilerplate specification is synthesized from the MRD and is used as the basis for all major procurements for the observatory.

1.9 Logistics Support Analysis

1.10 Producibility Analysis

1.11 Training Programs

1.12 Other System Engineering Tasks

2. TECHNICAL PROGRAM PLANNING AND CONTROL

This part of the SEMP shall identify organizaiton responsibilities and authority for system engineering management including control of subcontracted engineering; levels of control established for performane and design requirements and ocntrol methods to be used; plans and schedules for the design, development, assembly, integration, test and evaluation functions; and control of documentation. These areas are applicable to both the hardware and software engineering activities.

2.1 Program Risk Analysis

The FAME Risk Management (RM) approach is (i) identify and mitigate the "top 10" risks listed in Table (); (ii) use of cost reserves to "back up" program risk areas; and (iii) use of program descope options should reserves be insufficient. The PM maintains a "risk watch" list and reviews risk status with the SEIT monthly. The PM and the SEIT develop and categorize risk severity, and formulate mitigation plans for the PI. The PI oversees the RM process.

2.1.1 Technical Risk Identification

This process is formalized in Phase B. Table () lists "top ten" risk areas that may impact cost, schedule, performance, or science objectives. It provides a subjective rating of RM difficulty. Risk is rated high when it is difficult to mitigate or when it greatly impacts project cost, schedule, or performance. The key to managing risks is resolving performance and schedule issues before CDR.

2.1.2 Descope Options

The descope options are listed in Table (). If several of the mission top ten risks are not mitigated, then descope options will be necessary. A formal risk analysis is performed in Phase B with updates in Phase C/D. Our descope options follow agreed-upon processes (). If mission descope is considered, the PM provides the PI with a set of decision options and recommended actions. The PI determines the appropriate course of action.

2.1.3 Qualification of New Technologies

New technology H/W is flight-qualified using tailored test and analyses. Design and test history reviews determine suitability for use. Selective radiation screening for EEE parts without flight heritage is performed. Table () lists proposed new technologies for FAME and planned qualification approaches.

2.2 Engineering Program Integration

This section shall describe the contractor's proposed technical program planning and control functions for assuring the conduct of a totally integrated engineering effort.

2.3 Contract Work Breakdown Structure and Specification Tree

This section shall describe the manner in which the contractor's system engineering management shall develop the technical elements of the contractor work breakdown structure (CWBS) and how the enclusion of other contractual tasks required to form a complete CWBS shall be assured. The contractor shall develop a specification (not limited to contractual specifications) that relates to the CWBS.

2.4 Assignment of Responsibility and Authority

2.4.1 Systems Engineering and Project Management (WBS 1.0)

Summary element provides an integrated FAME mission management at USNO and project management function at NRL. Includes the principal investigator, the program manager, supporting business management and project administration functions, the Systems Engineering, Mission Assurance, Configuration Management, project website, and documentation support.

2.4.1.1 Prinicpal Investigator (WBS 1.1)

The projects principal investigator and the SAO's Project Scientist support.

2.4.1.2 Program Manager (WBS 1.2)

Includes all efforts associated with project-level planning, controlling, directing of prime and subcontractor efforts and interactions. Includes the data/report generation activities to produce internal and external documents. Includes program financial and schedule controls.

2.4.1.3 Business Management (WBS 1.3)

USNO business management.

2.4.1.4 Mission Design and Systems Engineering (WBS 1.4)

NRL's project-level engineering task to integrate the IPDTs and to ensure the spacecraft and instrument subsystems function properly to achieve system goals and requirements. Includes preflight trajectory analysis and ephemeris development.

2.4.1.5 Configuration Management (WBS 1.5)

Includes NRL's efforts to establish and maintain an integrated CM system for all project elements.

2.4.1.6 Performance Asurance (SR&QA) Management (WBS 1.6)

Includes NRL's support to establish and provide an integrated Mission Assurance (formerly Product Assurance) activity for the spacecraft, instrument, and GDS elements. Includes participation in the SEIT, and project oversight of Reliability Engineering, QA, software assurance, Safety, Contamination Control, and parts engineering. Quality Control costs are contained within the project elements.

2.4.1.7 Program Reserves (WBS 1.7)

Contains the spacecraft and instrument reserves held at the principal investigator's level.

2.4.2 Ground Data Systems (WBS 2.0)

Summary element, which includes the Phase B/C/D development and implementation costs.

2.4.2.1 Project Engineering and Management (WBS 2.1)

Includes project engineering and management support for the ground data systems.

2.4.2.2 Ground Command and Control (WBS 2.2)

This WBS supports the tracking services including contracts with the Deep Space Network. This line item includes all costs associated with this service for the specific proposed mission profile.

2.4.2.3 Science Operations Center (WBS 2.3)

This WBS supports upgrades for FAME specific hardware for the Science Operations Center (SOC).

2.4.2.4 Site Upgrades and Modifications (WBS 2.4)

This WBS supports upgrades for FAME specific hardware for the GDS, MOC and SOC.

2.4.3 Science (WBS 3.0)

This WBS includes the Phase B/C/D (pre-launch) support costs.

2.4.3.1 Science Team Coordination (WBS 3.1), Co-Investigators (WBS 3.2), Special Studies (WBS 3.3)

This WBS includes the costs for a team of co-investigators. This task addresses Science Team support to Mission Design and Definition, Instrument design, test, and calibration planning and execution. The task continues through Phase E and for a year after mission completion.

2.4.4 Instrument Payload (WBS 4.0)

This WBS includes all costs incurred to design, develop and fabricate the FAME instruments through delivery of the instruments to the spacecraft for integration. All LMMS ATC costs are maintained in this element for clarity. The LMMS ATC cost proposal for Spacebourne Payload Technology contained in the volume entitled FAME Supporting Financial Data.

2.4.5 Spacecraft Bus (WBS 5.0)

This WBS includes costs to specify, design, develop, and fabricate (or acquire) the spacecraft subsystems. Component level test and burn-in is included in this cost element. Cost for Mission Level Integration and Assembly, along with Systems Tests are addressed in WBS 6.0.

2.4.5.1 Spacecraft Bus Project Engineering and Project Management (WBS 5.1)

This WBS includes project engineering and management support for this element.

2.4.5.2 Spacecraft Subsystems (WBS 5.2)

This WBS is a summary element for all spacecraft subsystem costs. It includes component and subsystem specification, design, development, test, and integration into subsystems. Includes component level acceptance test and burn-in. Individual Level 4 elements for ADCS, Propulsion, EPS, CT&DH, Structures and Mechanisms, TCS, Telecommunications, and Flight Software.

2.4.5.3 Spacecraft Integration and Test (WBS 5.3)

This WBS supports integration of spacecraft subsystems into a fully tested, spacecraft bus to support the Instrument. It includes requirements specification, design, test procedures, GSE, test and evaluation, and test reporting.

2.4.6 Mission Systems Integration and Test (WBS 6.0)

This WBS is a summary element that includes I&T, test procedures, subsystem integration and alignments, MAGE and EAGE, other GSE, and handling equipment. Facility upgrade costs, and the facility costs for environmental tests are included.

2.4.6.1 MSI&T Project Engineering and Project Management (WBS 6.1)

This WBS includes project engineering and management support for this element.

2.4.6.2 MSI&T Integration and Test (WBS 6.2)

This WBS includes system level testing including, thermal-vacuum, electrical and mechanical functional, acoustic, vibration, electromagnetic compatibility/interference, and pyroshock.

2.4.6.3 MSI&T Electrical Aerospace Ground Equipment (WBS 6.3), Mechanical Aerospace Ground Equipment (WBS 6.4)

This WBS supports the specification, design, modification, development, integration, test and check-out of all EAGE/MAGE, related GSE, and handling equipment.

2.4.6.4 MSI&T Ground Software (WBS 6.5)

This WBS provides the software for the EAGE and MAGE used to support the spacecraft I&T process.

2.4.6.5 MSI&T Facility Upgrades and Modifications (WBS 6.6)

This WBS supports facility modifications needed to support this mission.

2.4.7 Launch Services (WBS 7.0)

This WBS is a summary element for launch services. It includes launch checkout and orbital operations support costs for launch planning, launch site support, launch-vehicle integration (spacecraft portion), and the first 30 days of flight operations. Includes transportation costs to the launch site.

2.4.7.1 Launch Services Project Engineering and Project Management (WBS 7.1)

This WBS includes project engineering and management support for this element.

2.4.7.2 NASA Launch Services (WBS 7.2)

This WBS includes launch vehicles and services that are provided by NASA under fixed price contracts.

2.4.7.3 Launch Processing (WBS 7.3)

This WBS includes launch checkout and orbital operations support costs for launch planning, launch site support, launch-vehicle integration (spacecraft portion), and the first 30 days of flight operations (excludes WBS 8.0 activities). Includes transportation costs to the launch site.

2.4.8 Mission Operations and Data Analysis (WBS 8.0)

This WBS cost element refers only to Phase E (post-launch), and has two major components: Mission Operations and Data Analysis. Mission operations comprises all activities required to plan and execute the science objectives, including spacecraft and instrument navigation, control, pointing, health monitoring, and calibration. Data analysis activities include collecting, processing, distributing and archiving the scientific data. MO&DA costs include all post-launch costs for people, procedures, services, hardware and software to carry out these activities. Includes the science team support costs post-launch.

2.4.8.1 MO&DA Project Engineering and Project Management (WBS 8.1)

This WBS includes project engineering and management support for this element.

2.4.8.2 Observation and On-Orbit Encounter Planning (WBS 8.2)

This WBS supports the orbit trajectory analysis.

2.4.8.3 Data Analysis, Archival, and Distribution (WBS 8.3)

This WBS includes data analysis, archive and distribution personnel, cost and the instrument.

2.4.8.4 Early On-Orbit Operations (WBS 8.4)

This WBS includes support of the orbit insertion process and fees.

2.4.8.5 Baseline Mission (WBS 8.5)

This WBS supports mission operations.

2.4.8.6 External Mission (WBS 8.6)

This WBS supports external mission costs that are not charged to NASA.

2.4.8.7 Ground and Science Infrastructure Management (WBS 8.7)

This WBS supports hardware and communication costs.

2.4.9 Education and Public Outreach (WBS 9.0), Education (WBS 9.1) and Public Outreach (WBS 9.2)

This WBS cost element includes all costs associated with developing and implementing programs for education and public outreach.

2.5 Program Reviews

FAME uses streamlined reporting requirements coupled with external reviews that allow the MIDEX Project Office to insight, understand progress, and exercise independent oversight. We encourage informal weekly telecons with the MIDEX Project Office and its SR&QA representatives. Reports, reviews, and their supporting materials use internal project products and processes as much as practical. Periodic design reviews using NHB 7120.5a milestone reviews, are baselined. USNO, in collaboration with NRL and LMMS ATC, prepare technical data packages for

distribution and presentation at the reviews. A NASA-appointed review panel conducts the reviews, and advance presentation copies are submitted for review 10 days before the formal presentation. USNO and NRL jointly establish a review board responsible to evaluate the reviews and the project's status. This board includes individuals with extensive experience with spaceflight programs and is independent of the FAME project. The MIDEX Project Office is invited to attend all technical meetings and reviews conducted by the Mission Team. Review Item Discrepancies (RIDS) are formally tracked and dispositioned, subject to PI and NASA concurrence. This section shall describe that manner in which the contractor's program review shall assess, reoptimize, and redirect the technical program effort during the course of the contractual effort.

2.5.1 Management Reviews

A comprehensive management review schedule will be established to provide effective communication between the FAME management elements and to ensure the timely resolution of problems. The primary consideration is to ensure appropriate level of management is apprised of problems and that these problems can be resolved with minimum impact on the project cost and schedule. The PM will periodically review status as an integral part of the management function. Special reviews will be conducted as needed. Table 18 lists the planned management reviews for the FAME project.

2.6 Design Reviews

2.6.1 Systems Requirements Review

The Systems Requirements Review (SRR) will describe/asses the design approach and verify that mission requirements are satisfied. It shall include the final Mission Requirements Document, the final Science Requirements Document, draft Interface Control Documents, Level 1 requirements, initial design and top-level system trades, alternate configurations, systems analyses, environments, top-level test and calibration plans, mission assurance plans and critical parts lists. From the SRR, SOWs and design requirements for major acquisitions such as the CCDs, solar arrays, and EEE parts should be defined.

2.6.2 Preliminary Design Review

The Preliminary Design Review (PDR) confirms that requirements, allocations, and specifications meet mission objectives. Includes final MRD and CONOPS, refined science requirements, final ICDs, and final segment specifications; List high-risk items and presents a prioritized mission descope plan; SR&QA, CMS and Verification Plans are presented. Completion of the PDR baselines the mission design.

2.6.3 Critical Design Review

The Critical Design Review (CDR) confirms that designs are ready for manufacturing, implementation, integration, and testing with acceptable risk. Technical problems and design issues are resolved without impacts to performance, reliability, or safety. All design areas are addressed. Completion of the CDR freezes the design, and results in fabrication and formal S/W coding, integration, and testing.

2.6.4 Test Readiness Review

The Test Readiness Review takes places before CPET to evaluate H/W status, and review plans. Confirms assembly and subsystem-level testing. Evaluates each deliverable's status integration. Completion of the TRR results in approval to proceed with CPET.

2.6.5 Pre-Ship Review (PSR)

The PSR is held immediately before shipment of the flight hardware to the installation site and before shipment of the observatory to the launch site. The PSR verifies that testing has been completed with no unacceptable open issues and evaluates the readiness of the hardware and software for flight. Completion of the PSR results in NASA approval to ship to the launch site.

2.6.6 Flight Readiness Review (FRR)

The FRR is conducted at the launch facility to verify overall readiness of flight hardware and software, and ground and launch support resources to achieve mission objectives. Ground systems, flight operations plans, and other operational I/F's are reviewed to assure support of on-orbit flight operations. Completion of FRR constitutes system acceptance.

2.7 Interface Control

Interface control shall be accomplished using Interface Control Documents (ICD). The ICD is a configuration-controlled item. The ICD has inputs from all parties affected and is signed by a senior representative of each represented organization. The three major ICDs that are planned for FAME include; (i) Spacecraft to Instrument ICD, (ii) Spacecraft to Ground ICD, and (iii) Spacecraft to Launch Vehicle ICD.

2.7.1 Spacecraft to Instrument Interface Control Document NSCT-ICD-FM002

The spacecraft to instrument ICD provides the interface requirements between the spacecraft bus and the instrument. This ICD provides specific details of the complete accommodation information for mechanical/structural, thermal, electrical, and command/data handling interfaces.

2.7.2 Spacecraft to Ground ICD NCST-ICD-FM003

The spacecraft to ground ICD provides the interface requirements between the FAME observatory and the Blossom Point ground station.

2.7.3 Spacecraft to Launch Vehicle NCST-ICD-FM002

The spacecraft to launch vehicle ICD provides the interface requirements between the FAME observatory and the launch vehicle.

2.8 Documentation Control

This section shall describe the contractor's proposed methods for controlling change to that internal technical data not subject to control by the configuration management system. This description shall be in sufficient detail to establish its consistency with the configuration management and change control requirements of the contract.

2.9 Engineering Testing

Electronics boxes shall undergo functional tests, temperature cycling, and random vibration, completing at least 200 hours of failure free operation.

This section shall identify what engineering efforts shall be accomplished leading to the contractual system test documentation. This section shall also include a discussion of test engineering effort not included in the other contractual documentation.

2.10 Tradeoff Studies

During Phase B, tradeoff studies are conducted to determine if the functional allocation of requirements has been optimized. Table 2-1 defines the major trade studies to be conducted. Results of major trade studies shall be written in Memo format and published on the project web site for review.

Table 2-1. Major Trade Studies Conducted

This section shall identify the major tradeoff studies to be accomplished and the general plan for their accomplishment. The basic method(s) for identifying, performing, and documenting the results of tradeoff studies shall be included.

2.11 Technical Performance Measurement

This section shall describe the plan for technical performace tracking and reporting, to include the following:

1) The identification of technical performance characteristics and technical program achievement parameters for each of the identified work elements of the CWBS. Those parameters proposed for routine reporting shall be denoted.

2) The methods, equations, or models for transforming parameter values of lower-level elements to that of higher-level elements and their sensitivities.

3) A planned profile for each of the parameters, the profile being an anticipated and time-phased variation, if any, for this parameter during the design, development, fabrication assembly and testing period. Events significant to the technical performance measurement shall be noted on these profiles.

4) A description of the means by which technical performance measurement shall be related to cost and shcedule performance measurement.

5) A sample technical performance report for an “out-of-tolerance” technical parameter. This shall include a planned value profile, the palnned value, demonstrated value, specification requirement, current estimate, and variance analysis.

6) A proposed compilation of the technical performance report(s) through which reporting shall be accomplished. This comilation shall denote whether on report shall be used for all reportable parameters or whether separate reports shall be employed on a subsystem or individual parameter basis or combination thereof.

7) The identification of technical performance achievements by developing parameters which address the following areas:
   a) Subsystem hardware delivery and operation.
   b) Computer equipment delivery and operation.
   c) Subsystem software (programs) development thru each phase of activity.
   d) Subsystem hardware/software integration.
   e) Specification and statement of work (SOW) requirements.
   f) Computer program documentation plan.
   g) Identification and acquisition of all design critical data.

2.12 Plans for Other Technical Program Tasks

This section shall describe the contractor's plans and procedures for other technical program planning and control tasks to be accomplished.

3. ENGINEERING INTEGRATION

This part of the SEMP shall describe the methods by which the contractor proposes to integrate the engineering efforts. It shall include a summary of each specialty program and cross reference the individual plans covering such specialty programs. Engineering specialty integration shall be discussed as well as the relationship of the engineering with the overall logistic efforts, including fault isolation methods (automatic, semiautomatic, manual) and their documentation, and how support equipment is identified.