

DRAFT
**EARTH EXPLORERS
PROGRAM**

**MISSION ASSURANCE
GUIDELINES & REQUIREMENTS**

January 2000

Earth Explorers Program Mission Assurance Guidelines & Requirements

Earth Explorers Program Mission Assurance Guidelines & Requirements

Approval by:

Earth Explorers Program Manager, Acting
Nicholas G. Chrissotimos
Project Manager
Earth System Science Pathfinder Project
Goddard Space Flight Center

Earth Explorers Program Mission Assurance Guidelines & Requirements

PREFACE

The purpose of this document is to serve as a set of requirements and guidelines to the Project/Mission Team in preparing an appropriate mission assurance program and implementation. Each section of this document contains requirements and a series of guidelines for implementing these requirements. These guidelines can be tailored to meet the specific needs of each mission, but must meet the intent of each requirement. Each Earth Explorers project/mission is required to be implemented in accordance with the best aerospace industry mission assurance practices, as applicable to that particular mission.

Earth Explorers Program Mission Assurance Guidelines & Requirements

1.0 OVERVIEW

It is the responsibility of the Project/Mission Team to plan and implement a comprehensive Mission Assurance program for all flight hardware, software, Ground Support Equipment (GSE), and mission operations. This responsibility extends to all of the mission subcontracts and suppliers. Only limited mission assurance insight is planned by the Earth Explorers Program Office and will be focused primarily on those activities that contribute most to product integrity. Deliverable documentation will be significantly reduced, provided the mission team maintains an adequate internal record keeping system that provides the necessary traceability for a program of this magnitude. The Earth Explorers Program Office will support and participate with the mission team in assuring that the Mission Assurance program being implemented is valid, complete, and effective. The Earth Explorers Program Office is prepared to assist the mission team in any aspect of mission assurance, and to be the mission team's focus for ready and regular access to the Goddard Space Flight Center's mission assurance expertise.

Previous Earth Explorers missions have been predominately single string systems, with emphasis on simplicity of design and cost control. Rigorous and disciplined systems engineering, combined with the prevention of problems by using high quality parts and materials and using high standards of workmanship, have allowed a limited reliability and quality assurance program, guarded by the test program, to achieve adequate reliability for a low cost. It is recommended that the mission team consider similar approaches that envelope all aspects of the mission development. A philosophy based on hurried design and development, followed by an extensive test and repair program, has been shown to be a costly and unreliable approach.

An agreement between the mission team and the Earth Explorers Program Office on the quality assurance, reviews, safety, design assurance and verification system to be implemented will be required prior to the confirmation of the mission.

The Project/Mission Team shall develop and implement an appropriate mission assurance program for flight hardware, software, ground support equipment and operations. The Project/Mission Team, together with the Earth Explorers Program Office and the Office of Systems Safety and Mission Assurance at the GSFC, will continually review and verify the proper implementation of this mission assurance program.

2.0 MISSION ASSURANCE

2.1 Quality System

The Project/Mission Team shall define and implement a quality system based on ANSI/ASQC Q9001-1994 that meets the intent of ISO 9001. The Project/Mission Team's quality system shall encompass all flight hardware, flight software and ground support equipment development, as well as mission operations.

2.2 Workmanship

The Project/Mission Team shall impose workmanship standards which help assure that the required mission lifetime and performance are met. The following commercial or NASA workmanship standards are given as guidelines and may be considered for use:

Soldering of Electrical Connections: NASA Technical Standard NASA-STD-8739.3, Soldered Electrical Connections

Earth Explorers Program Mission Assurance Guidelines & Requirements

Cabling, Harnessing, and Crimping: NASA Technical Standard NASA-STD-8739.4, Crimping, Interconnecting Cables, Harnesses, and Wiring. Note: MIL-STD-1130B, Connections, Electrical, Solderless Wrapped can be used if the missions are planning to use wire wrap for flight hardware or mission critical ground support equipment.

Conformal Coating and Staking: NAS 5300.4(3J-1), Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies

ESD Control: NASA Technical Standard NASA-STD-8739.7, Electrostatic Discharge Control (Excluding Electrically Initiated Explosive Devices)

Surface Mount Technology (SMT): NHS 5300.4 (3M), Workmanship Standard for Surface Mount Technology.

Note: SMT processes must be qualified to the mission profile and life expectancy of the mission.

Printed Wiring Board Design: ANSI/IPC-D-275, Design Standard for Rigid Printed Boards and Rigid Printed Board Assemblies, Class 3

Printed Wiring Board Procurement: IPC 6011 and IPC 6012, Class 3 as the basic specification requirements with GSFC S-312-P-003B, Procurement Specification for Rigid Printed Wiring Boards for Space Applications and other High Reliability Uses as a supplement.

The Project/Mission Team and their subcontractors shall provide printed wiring board coupons to GSFC, or to a GSFC approved laboratory, for test, analysis and review.

Fiber Optic: NASA Technical Standard NASA-STD-8739.5, Fiber Optic Terminations, Cable Assemblies, and Installation

2.3 Failure Reporting

A documented Failure Reporting System shall be implemented. A problem/failure report should be written for any departure from design, performance, testing, or handling requirement that affects the function of flight equipment, or ground support equipment that interfaces with flight equipment, or that could compromise mission objectives.

Reporting of failures to the Earth Explorers Program Office should begin with the first power application at the box, instrument, or spacecraft levels. This reporting should continue through formal acceptance of the hardware. For software problems, failure reporting should begin with the first test use of the software item with the hardware item. All failure reporting records should be submitted to the Earth Explorers System Assurance Manager for information. Either paper or electronic format is acceptable. The Project/Mission Team can use any failure report format they deem acceptable, as long as the Earth Explorers Program Office has concurred with their format. The Project/Mission Team should maintain failure reporting records of problems encountered at the lower levels of assembly for information.

3.0 REVIEWS

The implementation of the mission shall be periodically reviewed by a competent and independent assessment team or teams, to assure that satisfactory progress is being made toward meeting mission requirements.

Earth Explorers Program Mission Assurance Guidelines & Requirements

All required system level reviews will be conducted by, or be co-chaired by the GSFC. These reviews will concentrate on the critical system and end-to-end technical and programmatic aspects of the mission. Additional reviews at the subsystem level and at the system levels that are not covered by the required GSFC reviews, should be conducted by the Project/Mission Team. The review philosophy should be to provide and focus resources early and throughout the mission on engineering working level reviews, in order to identify and resolve potential problems before they reach formal, high-level system reviews. If requested to do so through the Earth Explorers Program Office, the GSFC could provide technical expertise for participation in these additional reviews. The GSFC is required to assess the thoroughness, competence and independence of the total review process and shall be invited to attend all technical reviews.

A Confirmation Review Process, will also be conducted. These reviews will be coordinated with the Project/Mission Team so that they can coincide with other reviews. It is the Project/Mission Teams responsibility to address all concerns and action items identified during these reviews

3.1 Required System Reviews

The required reviews for Earth Explorers projects/missions are the Preliminary Design Review (PDR), the Mission Design Review (MDR), Confirmation Readiness Review (CRR), the Critical Design Review (CDR), the Pre- Environmental Review (PER), the Pre-Ship/Operational Readiness Review (PSR/ORR), Mission Readiness Review (MRR), the Flight Readiness Review (FRR). The review chairman, in concert with the Earth Explorers Program Office and other directorates, appoints independent key technical experts as review team members. Every effort will be made to maintain continuity of the chairman and the key technical experts for the duration of the mission. Other experts will be added and/or deleted from the review team, according to the technical needs and phases of the mission. The scope and function of these required reviews is as follows:

Preliminary Design Review (PDR): The PDR shall occur during the mission Formulation Subprocess, but after final definition of the mission science and technical requirements. The purpose of the PDR is to examine preliminary designs of all mission subsystem and system components for technical feasibility with respect to the mission requirements and to assess the mission design at the subsystem and system levels as it relates to the mission requirements.

The Project/Mission Team, with participation from the Earth Explorers Program Office, will conduct the PDR. The GSFC Systems Review Office, Code 301, along with other independent technical experts from the GSFC will also participate in the PDR. The benefit of these additional reviewers will be to provide experienced expertise and to maintain review team continuity and familiarity through the other required reviews, as well as for the duration of the mission.

Mission Confirmation Reviews and Process

Mission Design Review (MDR): The MDR will be held at the end of the mission Formulation Subprocess and shall follow the PDR or be combined with the PDR. It combines the technical findings of the PDR with a programmatic and process review of the proposed mission implementation. The purpose of this review is to confirm:

- final design, fabrication and test plans for each subsystem
- final interface control documents
- mission integration and verification plans
- complete programmatic plan through launch
- requirements flow-down traceability

Earth Explorers Program Mission Assurance Guidelines & Requirements

- risk identification and mitigation plans, including descopes
- comprehensive cost, schedule and resource plans
- complete ground system architecture
- comprehensive system engineering plan
- final definition of mission science requirements
- thoroughly defined roles and responsibilities of all mission team members

The GSFC Systems Review Office, Code 301 and an appointee of the Earth Explorers Program Office will co-chair the MDR.

Confirmation Readiness Review (CRR): The CRR will be held after the MDR and is the Earth Explorers Program gate for mission approval to proceed into the Implementation Subprocess. The findings from the MDR are presented to the GSFC Governing Program Management Council (GPMC) for consideration and subsequent project/mission confirmation. The results from this review are either Mission Confirmation or conditional Mission Confirmation pending action item closure or Mission Termination.

Mission Confirmation Review: The GSFC PMC Chair and the Explorers Program Office present the results and recommendations of the CRR to the Associate Administrator, Office of Earth Science for concurrence and final approval for the mission to proceed into the Implementation Subprocess.

Critical Design Review (CDR): The CDR should occur after the design has been completed, but prior to the start of flight hardware manufacturing or coding of the flight software. It will emphasize implementations of design approaches, mission operations planning, as well as test planning for all flight systems. In the case of long lead procurements, manufacturing may be initiated prior to CDR as required to meet schedule.

Pre-Environmental Review (PER): The PER should assess the readiness of the flight hardware, software and required environmental test facilities to begin acceptance testing. The PER will also cover:

- design changes since CDR
- status of nonconformances
- test documentation (plans, procedures, waivers) and facilities readiness
- hardware and software configuration
- mission operations status

The PER should be held prior to the full system integration and functional test in preparation for environmental testing.

Pre-Ship Review/Operational Readiness Review (PSR/ORR): The mission PSR is conducted at the end of the mission Implementation Subprocess. The mission PSR shall verify that all system elements meet the requirements of the mission and are ready to proceed into final launch preparations. The mission PSR shall verify that testing has been completed with no unacceptable open issues and to validate the readiness of the flight hardware and software and ground system. Included as part of the above review is the Operations Readiness Review (ORR). This part of the review shall assess the readiness, and document the final details of the approach agreed to be used for flight operations. The mission PSR/ORR should cover:

- determination of completion of testing flight hardware and software
- verification of system requirements
- verification and documentation of final hardware and software configuration

Earth Explorers Program Mission Assurance Guidelines & Requirements

- identification and status of outstanding safety risks
- disposition of waivers, deviations, open issues
- results of compatibility testing of spacecraft and ground support equipment
- results of end-to-end system level testing and verification
- orbital operations plans
- mission operations, ground system and data processing system readiness
- launch system readiness (interfaces, vehicle)
- evaluation of the acceptance data packages

The result of this review shall be reported at the Mission Readiness Review. The mission operations agreement reached at the ORR cannot be changed without NASA concurrence.

The PSR will be chaired or co-chaired by the GSFC Systems Review Office, Code 301.

Mission Readiness Review (MRR): The MRR is typically held 4-6 weeks prior to launch. The review will cover all components of mission readiness; project status, science objectives and mission performance, instrument readiness, spacecraft readiness, ground system readiness, launch service readiness and launch site assessment, resolution of all open items, liens and waivers, public affairs plan and other topics as appropriate to ensure all aspects critical to mission success have been reviewed. The MRR is presented to the GSFC Governing Program Management Council (GPMC) for review and certification of the readiness of all mission components to proceed toward launch. The results of the MRR are presented to the Associate Administrator, Office of Earth Science.

Flight Readiness Review (FRR): The FRR shall take place at the launch site just prior to launch. This review is to certify final flight readiness of all mission elements. All open issues from the MRR must be resolved before the FRR.

The GSFC Systems Review Office, Code 301, will chair the FRR.

3.2 Additional Mission Reviews

Additional Mission Reviews are recommended as a supplement to the required reviews and shall be conducted by independent and competent outside consultants, peers or Project/Mission Team personnel. For these reviews, technical support may be requested from the Earth Explorers Program Office.

System Requirements Review (SRR): The SRR should be the first major mission review during the Definition Study Phase. The purpose of this review is to finalize mission science, operations and technical requirements. Traceability among these requirements should be demonstrated.

3.3 Peer Reviews

Engineering peer reviews typically occur during all phases of the project life cycle. These reviews are expected to be the most detailed of the technical reviews. It is the intent of the peer reviews that participants generate a detailed understanding of the component and subsystem design's ability to meet higher level system and mission requirements. Effective peer reviews will enable significant streamlining of the content of higher level formal reviews described in sections 3.1 and 3.2. To promote continuity of the whole review program, the Systems Review Office and other technical experts can be requested to attend any peer review session by the Project/Mission Team. Upon request, the Earth Explorers Program Office will supply technical expertise as

Earth Explorers Program Mission Assurance Guidelines & Requirements

required for participation in the areas undergoing peer reviews. The Earth Explorers Program Office shall be invited to attend all peer reviews. Some of the topics which should be addressed in the peer reviews are as follows:

- interface control design verification
- parts and materials review
- analysis and studies
- safety issues
- risk assessment, resolution and contingency plans
- procurements
- confirmation of technology items
- hardware and software configuration management
- detailed cost, schedule and resource availability
- manufacturability and testability
- integration and test planning, including test anomalies and resolution

The mission team is encouraged to focus resources from the beginning and throughout the mission development phase on engineering working-level reviews (peer reviews) to identify and resolve concerns prior to formal, system level reviews. The mission teams quality system is to track and close-out all actions items identified during these peer reviews to ensure that issues are resolved promptly at the lowest levels and before system level reviews. A list of action items/closures for each peer review should be maintained by the mission teams quality system and made available during system level reviews. Any open action items from any peer reviews should be addressed at the system level reviews.

Peer Review is defined as a detailed independent engineering design review focused at the Subsystem and box level, conducted informally with recognized internal or external experts having current detailed knowledge of the design specialties associated with the item under review. Primary design documentation, such as drawings, schematics, wiring diagrams, and analyses are the review vehicles. Its purpose is to substantiate a detailed understanding of the design's ability to meet all of its performance and interface requirements, to surface correctable problems early, and to ensure best known practices are used that enhance robustness by avoiding known or predictable problems. Timely, accurate insight, through action item documentation and follow-up activities, is vital to the process. For each review a written record must be kept of time, place, and attendees.

4.0 DESIGN ASSURANCE

4.1 Parts

The Project/Mission Team shall implement a parts program that assures mission reliability and performance requirements are met. A Failure Analysis shall be performed on all parts/components that fail after the final assembly of flight components and subsystems has been started. GSFC 311-INST-001, entitled Instructions for EEE Parts Selection, Screening, and Qualification for Grade 3 quality level may be used as a guide in selecting and processing parts. The Project/Mission Team should control the management, selection, application, evaluation, and acceptance of all parts through a parts control board, or another similar documented parts control system. Board members should be responsible for the review and approval of all parts for conformance to the GSFC 311-INST-001, Grade 3 quality level. The Project/Mission Team should maintain an EEE Parts Identification List prior to and during the Project/Mission Team's hardware built. This as-built list should be updated and submitted as part of the Mission Readiness Review.

Earth Explorers Program Mission Assurance Guidelines & Requirements

The Project/Mission Team should have access to and maintain knowledge of parts problems as reported in the Government Industry Data Exchange Program (GIDEP).

Destructive Physical Analysis (DPA) are not required as a screening for general parts usage, unless specific issues such as part failure history, GIDEP Alerts and Problem Advisories, new/unknown technology, or other similar concerns warrant it. The Parts Control Board (or system) participants should be responsible for determining which parts, if any, require DPA. DPA performance, when required, should be in accordance with GSFC S-311-M-70 or the Project/Mission Team's DPA procedure.

All Electrical, Electronic, and Electro-mechanical (EEE) parts should be derated in accordance with the guidelines specified in GSFC PPL-21, Appendix B. The Project/Mission Team should be responsible for the implementation and verification of the derating guidelines.

All EEE parts should be selected and design implemented to meet the maximum predicted mission ionizing radiation level requirements and to minimize Single Event Upsets (SEU) and be latch up immune.

4.2 Materials and Processes

The Project/Mission Team shall implement a Materials and Processes program. NASA Reference Publication 1124 entitled "Outgassing Data for Selecting Spacecraft Materials" should be used as a guide for materials selection on this program. Materials that have a total mass loss (TML) <1.00% and a collected volatile condensable mass (CVCM) <0.10% should be used on this program. Technical guidance in this area can be provided by the Earth Explorers Program Office. The Project/Mission Team should develop a single list which is all inclusive of the polymeric materials, inorganic materials, composites, lubricant usage, and the material process utilization. This list should be presented at the major reviews discussed in Section 3 of this Appendix.

Each Project/Mission Team should maintain a list of materials, processes, and appropriate usage records prior to and during the hardware development. This as-built list should be updated and submitted as part of the Mission Readiness Review.

4.3 Reliability

The Project/Mission Team shall plan and implement a reliability program that interacts with other mission disciplines including systems engineering, hardware design, parts selection, and systems safety. This program should be conceived and organized to effectively, efficiently, and responsively perform tasks that enhance the expected mission life-time. The Project/Mission Team should develop and implement a program plan that addresses mission objectives, assigns responsibilities, and schedules tasks relative to program milestones. The reliability program should at least respond to the following objectives:

I. Design

- a) Graceful degradation is a design objective.
- b) Reduce series complexity by eliminating unnecessary parts and components.
- c) Promote failure workarounds that allow continued successful but degraded operation.
- d) By design, wherever practicable, failures shall allow continued successful, albeit degraded operation.
- e) Isolate failure impact so that effects do not propagate to other functions.

Earth Explorers Program Mission Assurance Guidelines & Requirements

- f) Failure of non-critical functions shall not affect critical functions.
- g) Show that electrical stress applied to parts and devices meets derating requirements over the extremes of operating temperature range, voltage temperature range, and current variations.
- h) Parts meet total dose and single event effects radiation requirements.
Verification that a consistent reliability process is flowed down to subcontractor(s) and suppliers.

II. Manufacture

- a) An in-process inspection program that verifies hardware is assembled as designed.
- b) A verification program that assures specified manufacturing processes are followed.

III. Test

- a) A test program that verifies finished product meets specification.
- b) A test program that verifies finished product functions as designed.

A Failure Modes and Effects Analysis (FMEA) should be performed early in the design process to identify problem areas that do not meet these objectives. Corrective action may be recommended. The FMEA should be updated as the design matures. GSFC Procedure No. S-302-89-01 entitled "Procedures for Performing a Failure Modes and Effects Analysis" and/or MIL-STD-1629A, "Procedures for Performing a Failure Mode, Effects and Critical Analysis" can be used as guides. The FMEA should be available for

review by the Earth Explorers Program Office. Procedures for performing a FMEA are available on the World Wide Web at URL address (<http://arioch.gsfc.nasa.gov/302/ssromisc.htm>).

4.4 Software

The Project/Mission Team shall employ a structured program for the development of software. The program shall address appropriate development life cycle phases such as: requirements analysis, design, code and unit test, integration and build test, performance verification, and maintenance. Code produced shall be structured, error-free, and maintainable.

During the preliminary design process, the Project/Mission Team shall establish and document software requirements and any appropriate external interface specifications and user guides.

The Project/Mission Team shall participate in a program of internal and external software reviews to validate software requirements, design, operating characteristics, and external interface requirements.

The Project/Mission Team should employ a software configuration management process to manage requirements, code, documentation, and data, and to track and report on the status of changes to them. The process should include a means to record, track and disposition identified discrepancies in the product (i.e., non-conformance control).

5.0 VERIFICATION

Each Project/Mission Team shall conduct a verification program to ensure that the flight hardware meets the specified mission requirements. The program should consist of functional demonstrations, analytical investigations, physical measurements and tests that simulate all expected environments. Each Project/Mission Team should provide adequate verification documentation including a verification plan and matrix, environmental test matrix, and verification procedures.

Earth Explorers Program Mission Assurance Guidelines & Requirements

Guidelines for developing a Verification program are available on the World Wide Web at URL address (<http://arioch.gsfc.nasa.gov/302/verifhp.htm>).

6.0 CONTAMINATION

The Project/Mission Team shall identify contamination requirements and establish and maintain a contamination control program consistent with mission requirements.

7.0 INDEPENDENT MISSION OPERATIONS REQUIREMENTS

Missions being operated by a PI independent of NASA must meet the following additional requirements. After on-orbit checkout, incident reports must be provided to the GSFC Earth Science Mission Operations (ESMO) Project in accordance with "GSFC Flight Program Incident Reporting System Guidelines". Weekly orbital status summary reports shall be provided to ESMO. It is the PI institution's responsibility to contractually ensure the availability of spacecraft developer support of anomaly resolution efforts during the mission's operational phase. Structured management approaches to risk management and orbital mission configuration control must be in place during the operational phase. An annual mission risk assessment status report shall be provided to ESMO.