Version: 04-02

LASER INTERFEROMETER SPACE ANTENNA

Laser Interferometer
Space Antenna (LISA)

SYSTEM ENGINEERING MANAGEMENT PLAN (SEMP)

DRAFT

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GSFC·JPL

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1.0 INTRODUCTION

1.1 PURPOSE

The plan is intended to document the activities to be performed by the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center's (GSFC's) System Engineering Office in support of the Laser Interferometer Space Antenna (LISA) Project's mission formulation. The System Engineering Office will update the System Engineering Management Plan (SEMP) near the end of the Formulation Phase in preparation for the Implementation Phase.

1.2 APPLICABLE DOCUMENTS

The following documents, or latest revision thereof, are applicable to the development of this plan.

ESA-SCI(2000)11	Laser Interferometer Space Antenna: A Cornerstone Mission for the Observation of Gravitational Waves System and Technology Study Report, July 2000
JSC 49040	NASA System Engineering Process
NPG 1000.2	NASA Strategic Management Handbook
NPG 7120.5A	NASA Program and Project Management Processes and Requirements
SP-610S	NASA Systems Engineering Handbook
GPG 7120.2	Project Management
GPG 7120.4	Risk Management
GPG 8700.1	Design Planning and Interface Management
GPG 8700.4	Integrated Independent Reviews

1.3 MISSION OVERVIEW

The LISA Project is a joint mission between NASA and the European Space Agency (ESA). The primary purpose of the LISA mission is detect and study gravitational waves in the low-frequency range (10^{-4} to 10^{-1} Hz) from galactic and extra-galactic binary systems. Gravitational waves are one of the fundamental building blocks of the theoretical picture of the universe.

The LISA mission consists of three identical sciencecraft forming an equilateral triangle, separated by $5x10^6$ km. The triangular formation is placed in a heliocentric orbit, 20° behind the Earth. The plane of the triangle is tilted 60° with respect to the ecliptic. The plane of the triangle rotates approximately 1° per day and completes one revolution around the Sun in approximately 360 days. The constellation of three sciencecraft act as a giant Michelson-type optical interferometer measuring the distortion of space caused by passing gravitational waves. Figure 1-1 shows the LISA on-orbit configuration.

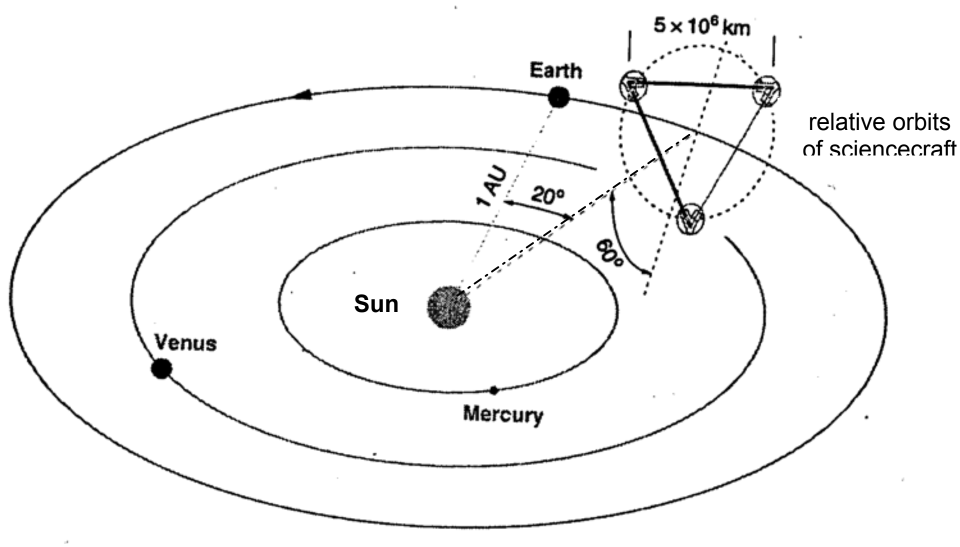

Figure 1-1. LISA Configuration in Orbit

Each sciencecraft consist of one Y-shaped payload. The payload consists of all items enclosed by and including the Y-shaped tube. Inside the Y-shaped payload are two optical benches. Within each optical bench is a free floating proof mass. The relative distance between the proof masses changes with the passing of a gravitational wave. This change in distance between the proof mass is measured using laser interferometry. The proof masses act as the reflectors or ends of the interferometers.

Each sciencecraft is attached to its own propulsion module. The propulsion module is used to transfer the sciencecraft from the Earth orbit to its final orbit. Once the sciencecraft reaches its final orbit, the propulsion module is jettisoned. Each sciencecraft reaches its final orbit in approximately 13 months. The three sciencecraft and three propulsion modules constitute the flight segment.

Each sciencecraft carries two 30-cm diameter steerable antennas used for transmitting science and engineering telemetry, stored on board for TBD days, at a rate of 7 kbps in the X-band to NASA's 34-meter Deep Space Network (DSN).

The nominal mission lifetime is TBD years with a goal of 10 years (extended).

1.4 SYSTEM SEGMENT OVERVIEW

The overall LISA system is composed of four major segments as described below and shown in Figure 1-2.

1.4.1 Flight Segment

The Flight segment consists of the three sciencecraft, each comprised of two laser payloads and the support subsystems (sciencecraft) required for operation during the mission, plus the ground support equipment (GSE). The Flight segment also includes the three propulsion modules.

1.4.2 Launch Segment

The Launch segment consists of the launch vehicle and associated services, facilities, and properties needed to integrate three sciencecraft and their respective propulsion modules onto the launch vehicle, and conduct pre-launch testing with the remainder of the ground system.

1.4.3 Ground Operations Segment

The Ground Operations segment includes all of the facilities needed to plan, schedule, execute, monitor, and maintain the health and safety of the sciencecraft during the mission.

1.4.4 Science Data Processing Segment

The Science Data Processing segment provides those facilities and equipment needed to receive, archive, and distribute processed or raw science data products to the investigator/user facilities.

1.5 DEFINITIONS

The following definitions will be used during the LISA mission when defining the LISA system.

Mission System	Definitions
Segments	Flight, Launch, Ground Operations, and Science Data Processing
Elements	Sciencecraft, Payload, Launch Vehicle, and Ground System
Support Subsystems	Structural, Power, Attitude Control, Thermal, Propulsion, Tracking, Telemetry, and Command (TT&C), and Communications and Data Handling (C&DH)
Components	TBS

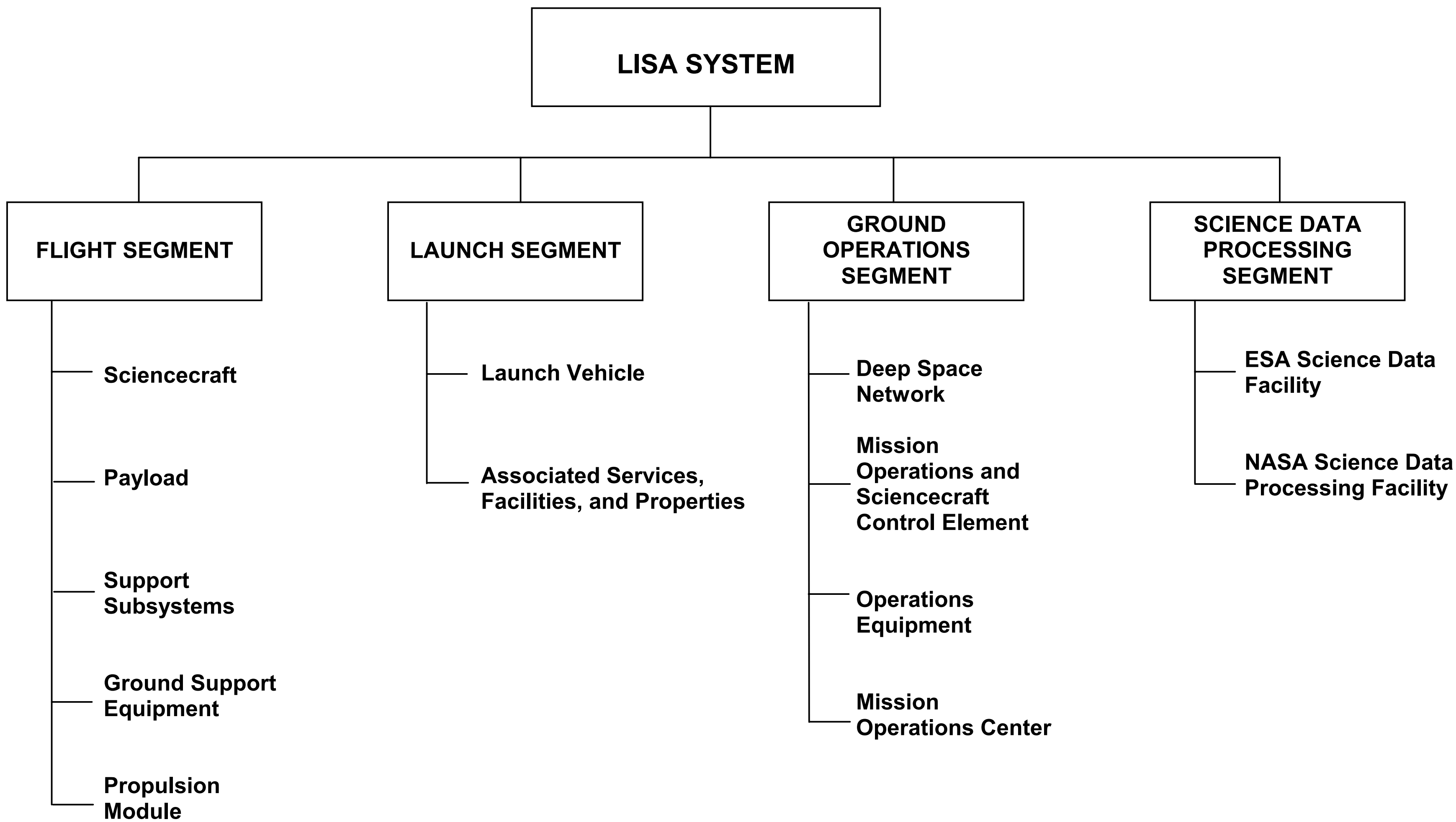

Figure 1-2. LISA Segments

1.5.1 Instrument

The Instrument consists of the three sciencecraft functioning as a single instrument.

1.5.2 Payload

The payload encompasses all items enclosed by and including the Y-shaped payload thermal shield which also includes lasers and interferometer electronics for the science mission.

1.6 PROJECT SCHEDULE

Figure 1-3 shows the long-term schedule for the NASA/ESA collaborative LISA Project. This schedule assures approval of the project by NASA and ESA in the year 2007 and a 3-year development program leading to a launch in the year 2010.

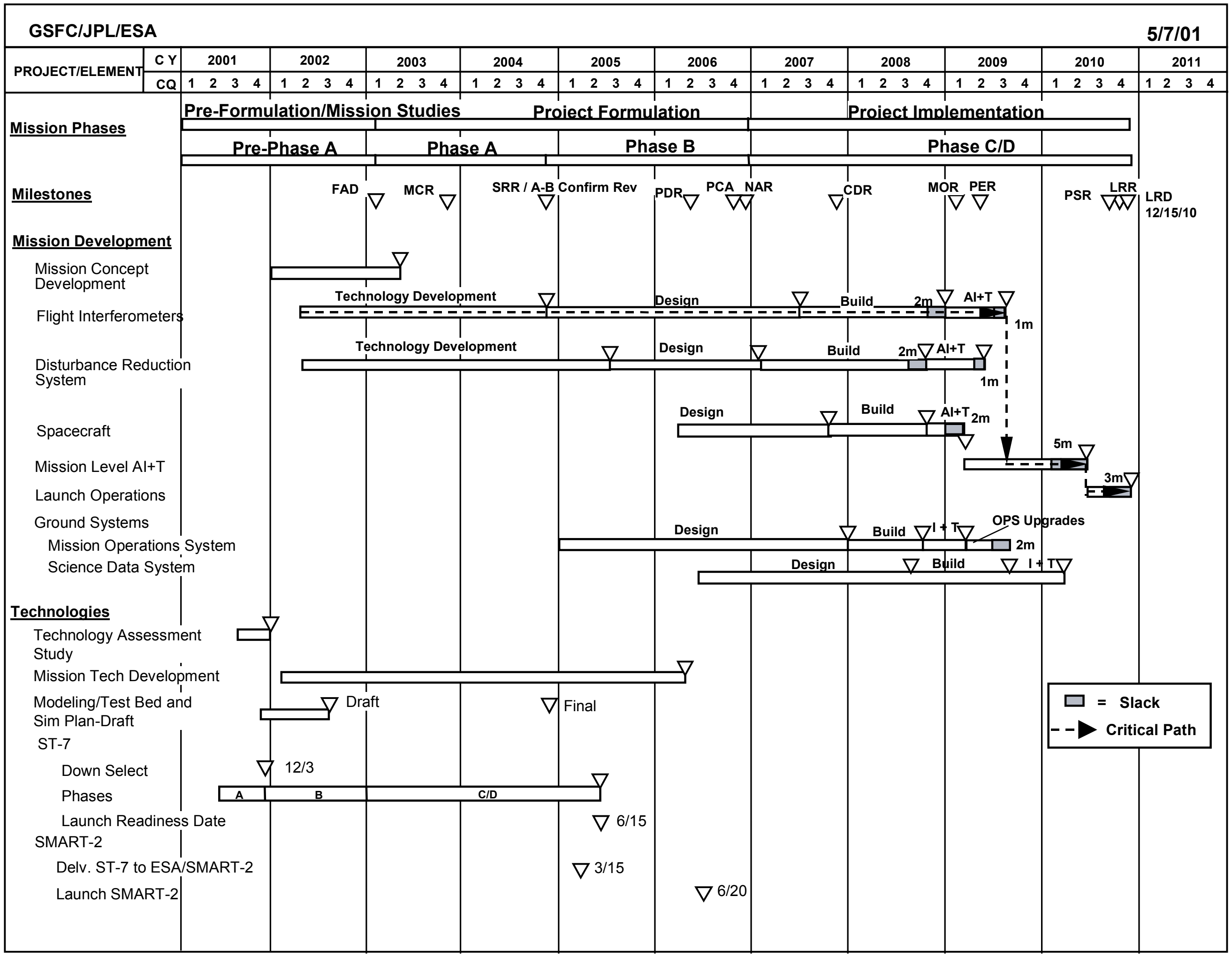

Figure 1-3. LISA Project Long-term Schedule (Draft)

2.0 SYSTEM ENGINEERING LIFE CYCLE AND REVIEWS

The System Engineering Life Cycle is defined within Goddard Procedure and Guideline (GPG) 7120.2, Project Management, as a set of phases – Formulation, Approval, and Implementation. The LISA SEMP uses the familiar Pre-phase A, Phase A, Phase B, Phase C, and Phase D terminology described by the NASA Systems Engineering Handbook, SP-610S. This section describes each phase and shows the major reviews associated with each phase and the phase transitions.

2.1 CONCEPT STUDIES

Pre-Phase A: Advanced Studies – The advanced studies occur prior to the initiation of the LISA System Engineering Life Cycle. Although not a part of the life cycle, advanced studies serve as the first step in determining new and potentially promising missions deserving of further study. These studies support the establishment of a suitable project through exploring perceived needs and potential solutions to meet them. The Pre-Phase A function must be completed prior to initiating the Formulation phase of the life cycle.

2.1.1 Major Pre-Phase A Gate

The major technical review to transition from Pre-Phase A to Phase A is the Mission Concept Review (MCR). The purpose of this review is to demonstrate that the mission objectives are complete and understandable; to confirm that the mission concept demonstrates technical and programmatic feasibility of meeting the mission objectives; and to confirm that the customer's mission need is clear and achievable.

The Formulation Authorization Document (FAD) is a major programmatic gate of the life cycle process which is the primary input to the LISA Project formulation sub-process. It authorizes the level of formulation of the project whose goal will fulfill part of NASA's Strategic Plan.

2.2 FORMULATION

Phase A and Phase B comprise the Formulation portion of the System Engineering life cycle. Proper planning during the Formulation period is essential to the successful execution of the Implementation phase. Phase A, or preliminary analysis, determines whether a candidate mission is needed, feasible, and compatible with the NASA strategic plan.

Phase B, or the definition phase, thoroughly defines the project requirements and provides sufficient detail definition of the mission to establish a baseline design capable of meeting the mission needs.

2.2.1 Major Phase A Gate

The A-B Confirmation Review is the major gate between Phase A and Phase B. The mission concept including requirements, operations concept, and architecture and design is reviewed at a high level during this review.

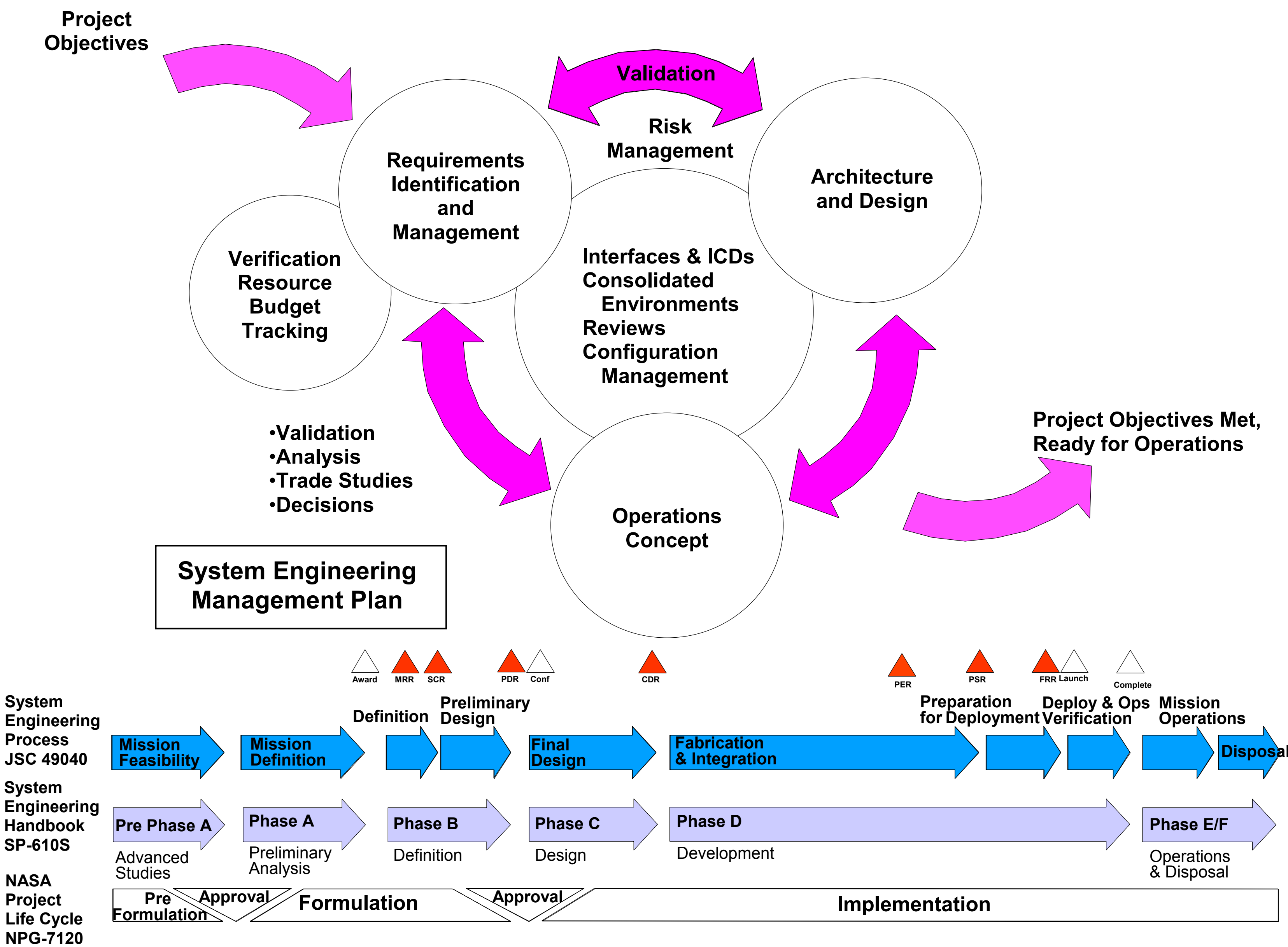

Figure 2-1. LISA Key System Engineering Functions

2.2.2 Phase B Reviews

The LISA System Requirements Review (SRR) is a formal review chaired by the GSFC Flight Assurance Office. However, the review board will be comprised of both ESA and NASA representatives.

The SRR is held to ensure that the objectives and requirements of the LISA mission are understood. It also confirms that the system-level requirements meet the mission objectives and that the system level specifications are sufficient to meet the project objectives. This review is held a few months after the beginning of Phase B.

The System Concept Review (SCR) is held to ensure that the mission design and architecture and the operations concept meet the requirements. This review is held a few months after the SRR.

2.2.3 Major Phase B Gate

The Preliminary Design Review (PDR) is a major gate between Phase B and Phase C. It will demonstrate that the system architecture, designs, and operations concept developed during Formulation have been validated by enough technical analysis and design work to establish a credible, feasible design. The PDR also demonstrates the following: the LISA mission architecture and design still meets all system requirements; the best design options have been selected from trade studies and analyses: internal and external interfaces are identified and understood; risk management has been integrated into the design and development activities; and prioritized risk areas have mitigation approaches defined.

2.3 IMPLEMENTATION

Two phases comprise the Implementation portion of the System Engineering life cycle, Phase C (detailed design) and Phase D (fabrication and integration). The purpose of Phase C is to establish a complete design that is ready to fabricate, integrate, and verify. The purpose of Phase D is to build, integrate and verify the system designed in Phase C, deploy it, and prepare for operations.

2.3.1 Major Phase C Gate

The Critical Design Review (CDR) confirms that the project's system, subsystem, and component design, derived from the preliminary design, is of sufficient detail to allow for orderly hardware/software manufacturing, integration, and testing, and represents acceptable risk. Successful completion of the CDR freezes the design, and concludes Phase C.

2.3.2 Phase D Reviews

The Pre-Environmental Review (PER) is a major gate that occurs before the start of environmental testing of the sciencecraft system. It establishes readiness of the system for test and evaluates the environmental test plans.

The Pre-Shipment Review (PSR) is a major gate of the life cycle process and is used to present status of systems prior to shipment. It is a technical and programmatic review conducted prior to shipment of the sciencecraft to the launch site. It establishes readiness to ship flight hardware, and is also a review of launch site activity plans.

The Launch Readiness Review (LRR) is used to demonstrate readiness for launch and operations. It is a formal review to access the overall sciencecraft readiness to support mission objectives.

The Flight Readiness Review (FRR) examines tests, demonstrations, analyses, and audits that determine the sciencecraft's readiness for a safe and successful launch and for subsequent flight operations. It also ensures that all flight and ground hardware, software, personnel, and procedures are operationally ready.

The Mission Operations Review (MOR) is a formal review chaired by the GSFC Flight Assurance Office and concentrates on the ground system and flight operations preparations.

3.0 KEY SYSTEMS ENGINEERING FUNCTIONS

Mission Systems Engineering is only one of the processes that are executed during the Formulation Phase. Key Systems Engineering functions during both the Formulation and Implementation phases are shown in Figure 3–1. The major Systems Engineering elements of the Formulation Phase include requirements identification and management, operations concept definition, and architecture and design synthesis. The operations concept definition, architecture and design synthesis, and requirements analysis are generally done in parallel. Each activity contributes to the refinement of the others.

The following paragraphs in this section describe the execution of the major Mission Systems Engineering processes and products that will support the LISA Formulation Phase.

3.1 REQUIREMENTS IDENTIFICATION AND ANALYSIS

3.1.1 Requirements Definition

The following definitions will be used during the LISA mission when defining requirements.

System and Engineering Levels	Requirements Definition
Program, Project, HQ	Level 1
Mission, System, Segment	Level 2
Sciencecraft, Payload, Ground, Element	Level 3
Subsystem	Level 4

The LISA mission requirements will be organized into a hierarchy and will provide the mechanisms for specifying what is necessary down to the lowest level of the system. Figure 3.2 shows how the requirements hierarchy is structured. The Requirements Working Group is responsible for assigning each Level 1, 2, and 3 requirements to an owner. Each requirement will be assigned an owner by SRR. The owner is responsible for specifying the method of verification no later than PDR.

The LISA requirements will also be organized into two categories: functional requirements and performance requirements. Functional requirements are concise statements of what a system must do to satisfy its objectives. Performance requirements are concise statements of how well a system must perform its functions to satisfy its objectives. The performance requirements will be attached underneath their respective functional requirement and *not* in a separate performance requirements document.

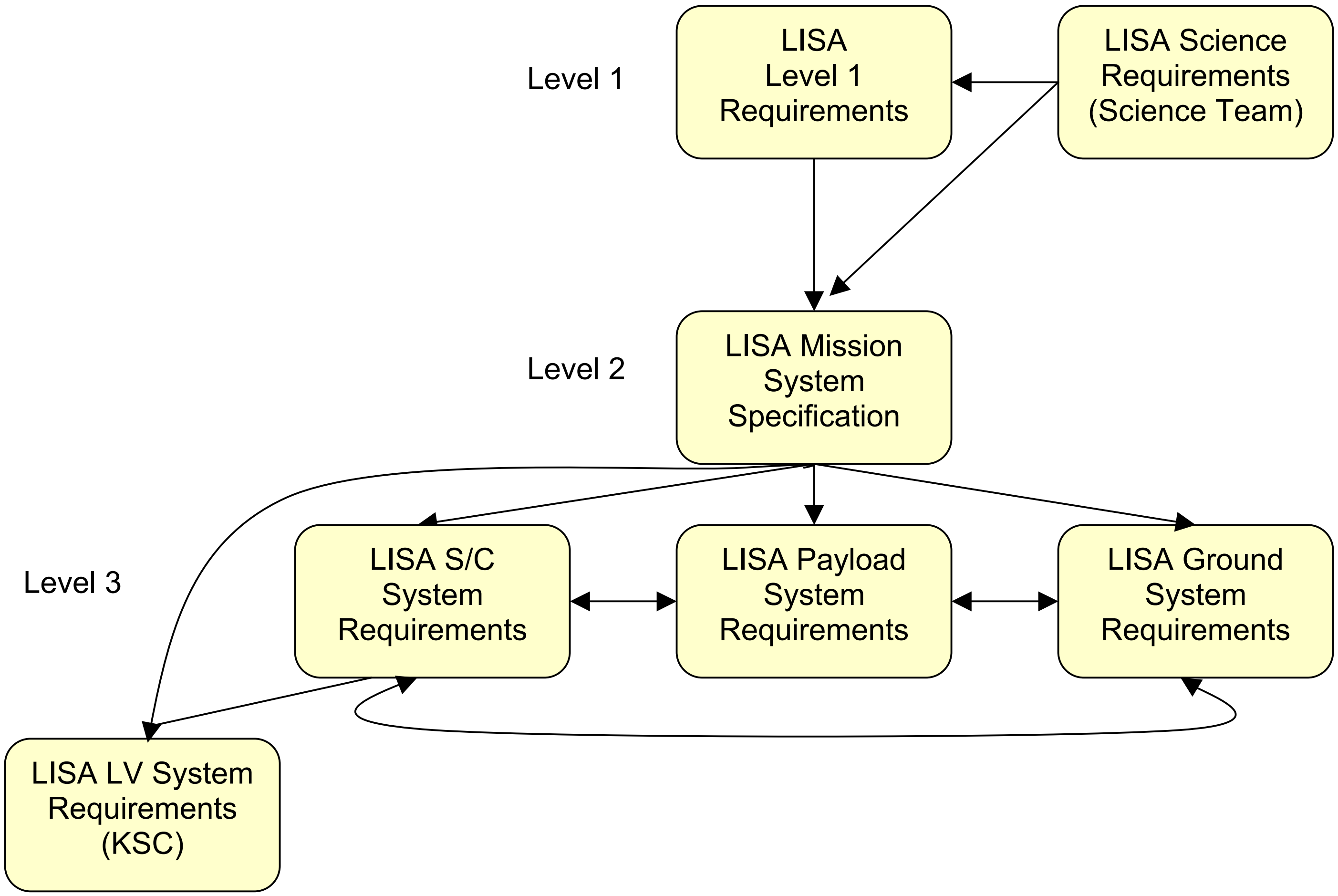

Figure 3-2. LISA Requirements Documentation Tree

3.1.2 Requirements Between Elements

Some requirements flow between elements or are common amongst all elements. These requirements will be documented in the Mission System Specification (MSS) or in one the following documents:

- Electrical Systems Specification
- Environmental Specification
- Thermal Specification
- Electromagnetic Interference/Electromagnetic Compatibility (EMI/EMC) Plan
- TBS

3.1.3 Requirements Management

The System Engineering Office will set up and maintain one common database for tracking LISA requirements. The Mission System Engineering Manager (MSEM) and each element System Engineer (SE) is responsible for providing inputs to this common database including the requirement, owner, parent requirement, rationale, verification method, verification results, and status. The System Engineering Office will conduct a trade study during Pre-Phase A, to determine the optimum requirements tracking system for LISA. The System Engineering Office will setup and maintain this database after the Level 1 Requirements document and MSS are stable. The Requirements are placed under configuration control after the SRR.

3.1.4 Requirements Validation

There are two parts to the requirements validation. The first ensures that the mission architecture, design, and the operations concept meets the requirements. It asks the question "did we build the right system?" The Integrated Design Team will validate the requirements after the baseline mission and system architecture and operations concept is established and the MSS is stable. The MSS, mission architecture, and operations concept are updated simultaneously to reflect consistency.

The other part of requirements validation is ensuring that higher-level (parent) requirements flow to lower-level (child) requirements and that each lower-level requirement has a "parent" requirement. During the validation process, the Integrated Design Team will make sure each requirement is verifiable, achievable, and traceable to a higher-level requirement or science objective.

3.1.5 Requirement Products

3.1.5.1 Level 1 Requirements Document. The LISA Level 1 Requirements Document serves as the top level for the requirements flow-down. It defines science requirements, mission parameters, constraints, and programmatic boundaries (e.g., top-level science and mission requirements, external agreement requirements, and NASA/ESA constraints).

The Requirements Working Group, with members from the System Engineering Office and LIST (NASA and ESA) will draft the Level 1 Requirements Document. They will release two drafts of this document to LIST and the project for comments prior to sign off. The Level 1 Requirements Document is signed off at the Phase A-B Confirmation Review.

3.1.5.2 Mission System Specification. Once the first draft of the Level 1 Requirements Document is stable, the Requirements Working Group will draft the LISA MSS (Level 2). The MSS contains both functional and performance requirements which, when met by the system, will satisfy the Level 1 requirements and mission objectives. The MSS contains all requirements that cross between elements including error allocations, control loops, etc, and provides the top-level requirements for the lower-level documents. Also, the MSS will contain a verification matrix describing how each requirement is verified.

The Requirements Working Group will issue two drafts of this document for comments before it is signed off. The MSS is the responsibility of the System Engineering Office.

After the Level 1 Requirements Document and the MSS are stable, the following requirements documents will be generated.

3.1.5.3 Payload Functional Requirements Document. The Payload Functional Requirements Document defines the functional requirements for the payload system and allocation of Level 3 requirements to the payload subsystems. This document will include a detailed description of the functionality of the payload and a list of interfaces between the payload and subsystems.

3.1.5.4 Spacecraft Requirements Document. – to be supplied

3.1.5.5 Ground System Requirements Document. – to be supplied

3.1.6 Requirements Reviews

The LISA System Requirements Review (SRR) is a formal review chaired by the GSFC Flight Assurance Office. The review board is comprised of both ESA and NASA representatives. The SRR is held to ensure that the objectives and requirements of the LISA mission are understood. It also confirms that the system-level requirements meet the mission objectives and that the system level specifications are sufficient to meet the project objectives. The MSS is formally reviewed at the SRR and is signed shortly thereafter.

3.2 OPERATIONS CONCEPT DEVELOPMENT

The Operations Concept definition begins in Pre-Phase A and a baseline is established at the end of Phase A. It is developed in parallel with the architecture and design activities and the requirements flow-down. The Operations Concept defines and addresses the following: ground versus flight allocation, operational modes and configurations (e.g., science, launch, checkout, calibration, etc.), data flow diagrams, storage and downlink, ground station utilization, and operations testing prior to launch. The Operations Concept is refined throughout the mission life cycle and eventually becomes the LISA Operations Plan.

3.2.1 Operations Concept Products

An early product Operations Concept activity is a set of candidate operations concepts. The Integrated Design Team will conduct trade studies to determine which candidate concept is consistent with the architecture and design and best meets the requirements, including cost and schedule requirements. All trade studies will be documented and available on the LISA web site. The Operations Concept will be formally reviewed at the SCR and a baseline established shortly after. Once the baseline is established, the Operations Concept will be placed under Configuration Control.

3.2.2 Operations Concept Reviews

There are two major reviews conducted related to the Operations Concept activities during Formulation: the System Concept Review (SCR) and the Preliminary Design Review (PDR). The SCR is held during Phase B and will ensure that the baseline Operations Concept meets the requirements. The PDR is held at the end of Phase B and will ensure that the Operations Concept are defined in enough detail as to proceed to Phase C without risk of major changes.

3.3 MISSION ARCHITECTURE AND DESIGN

The Architecture and Design definition begins in Pre-Phase A and a baseline is established at the end of Phase A. It is developed in parallel with the Operations Concept activities and the requirements flow-down. The ESA Final Technical Report (FTR) is the starting point for this activity. This activity decomposes the total system into its major parts that then become the hierarchy for lower level interfaces and specifications.

The System Engineering Office is the keeper of the baseline architecture. The architecture and design specification and block diagram will be formally reviewed at the SCR and a baseline established. Once the baseline is established, the architecture and design will be placed under Configuration Control.

3.3.1 Architecture and Design Products

3.3.1.1 Block Diagrams. An early product of the Architecture and Design activity is a block diagram of the system. The Integrated Design Team (IDT) is responsible for generating the block diagram. Once the block diagram is stable, an informal configuration control process will be set up to track and approve changes. Once changes are approved, IDT will update the block diagram to reflect the current baseline architecture, and distribute it to the LISA team. The system block diagram will be frozen and placed under formal configuration control shortly after the PDR. Changes to the system after PDR will impact cost and schedule. The block diagrams will be available on the LISA Project web site.

3.3.1.2 Architecture and Design Specification. The Architecture and Design Specification is a description of the total system and its decomposed major parts. The major parts of the system include the sciencecraft, payload, ground system, support subsystems and boxes as well as hardware and software functions. The major parts then become the hierarchy for lower level interfaces and specifications. The Architecture and Design Specification also includes a list of Interface Control Documents (ICDs) that need to be produced. It is the responsibility of the IDT to draft the Architecture and Design Specification. It will be available on the LISA Project web site.

3.3.1.3 Trade Studies. The IDT will evaluate the current baseline design in the FTR and determine which trade studies need be conducted. Trade studies and analysis are conducted to determine which architecture best meets the requirements (including technical, cost and schedule requirements) while being compatible with the operations concept. This process of refining the design through analysis and trade studies will continue throughout Phase A and Phase B until PDR.

The lead person conducting the trade study is responsible for documenting the trade study either in a brief white paper, power point chart, or other sensible form. The information contained in the white paper includes a summary of the trade, analysis performed, factors leading to the result, and the conclusion. All trade studies will be available on the LISA Project web site.

3.3.2 Architecture and Design Reviews

There are two major reviews related to the Mission Architecture and Design activities during Formulation: the SCR and the PDR. The SCR is held during Phase B and will ensure that the baseline architecture and design meets the requirements. The PDR is held at the end of Phase B and will ensure that the architecture, block diagrams, and interfaces are defined in enough detail as to proceed to Phase C without risk of major changes.

3.4 VERIFICATION

The System Engineering Office will ensure that the team builds the system right by verifying the design and implementation against the requirements. During the requirements definition process, the method of verification (i.e. analysis, test, and inspection) for each requirement is identified. Each element System Engineer is responsible for identifying the method of verification for their requirements. Each requirement and associated verification method will be assigned an owner by SRR. The owner is responsible for specifying the method of verification no later than PDR.

3.4.1 Verification Products

3.4.1.1 Verification Matrix. The Verification Matrix is developed at the time the requirements are written. This is a simple spreadsheet identifying the method of verification (analysis, test, inspection). The verification matrix is used to develop the Verification Plan.

3.4.1.2 Verification Plan. The Verification Plan is a detailed document stating how each requirement is verified. The plan includes the Ground Support Equipment, Bench Test Equipment, Engineering Units, tools, facilities, etc. required to verify each requirement. The owner of each requirement is responsible for generating a verification plan for their assigned requirements by the PDR.

3.4.1.3 Integrated Modeling Plan. – to be supplied

3.5 INTERFACES AND ICDS

During Phase A, the Integrated Design Team will define the *major* interfaces and assign an owner responsible for generating ICD. During Phase B, the Integrated Design Team will define the *detailed* interfaces and assign the owner responsible for generating those ICDs. The System Engineering Office will define the format for the ICDs. Interfaces will be kept as simple as possible so the number of ICDs is reasonable and manageable. All ICDs will be placed on the LISA web site.

In general, interfaces between elements and interfaces between agencies are the responsibility of the Mission System Engineering Manager (MSEM). Intra-element interfaces are the responsibility of the element System Engineer.

3.6 RESOURCE BUDGETS AND ERROR ALLOCATION

3.6.1 Resource Budgets

The System Engineering Office is responsible for tracking the system level resources. These include mass, power, volume, data, etc. Each element System Engineer is responsible for tracking their resources in accordance with the system budget. The System Engineering Office will establish the resource budgets during Pre-Phase A and will updated them bi-annually.

During Phase A, the System Engineering Office will set up a centralized tracking system for all resources and budgets. The Mission System Engineer and each element SE is responsible for providing input to the centralized tracking system.

3.6.2 Error Allocation Budget

The System Engineering Office is responsible for establishing and maintaining the error allocation budget. During Pre-Phase A, the Integrated Design Team will establish a draft top down error allocation budget and iterate it with the key subsystems to see if the allocation is feasible. A baseline error allocation budget will be established during Phase A. The error allocation budget will be available on the LISA Project web site.

3.6.3 Margin Management Philosophy

The System Engineering Office is responsible for allocating and maintaining technical resource margins. During Pre-phase A and Phase A, the System Engineering Office will hold a 30 percent margin on technical resources. Past experience shows that 25 percent of the total margin is allocated by the PDR and an additional 25 percent is allocated by the CDR. The System Engineering Office will follow these guidelines when reviewing the margin budgets throughout the LISA lifecycle.

The Integrated Design Team will allocate the margins. This team reviews the requests made, explores different options and workarounds, and either grants or refuses the request. Margin status will be presented monthly to the Project Manager.

3.7 RISK MANAGEMENT

3.7.1 Risk Management Plan

TBS

The Risk Management Plan identifies the process to be used for the management of risks to the definition and implementation of the mission, including technical, cost, schedule, and programmatic.

3.8 ENVIRONMENTAL KNOWLEDGE

TBS

3.9 CONFIGURATION MANAGEMENT

3.9.1 Configuration Management System

The LISA Configuration Management (CM) system functions as a library for documentation control, access, and dissemination. Documents are placed into the library to serve as a single, configured, point-of-reference for the LISA team. The documents placed under configuration control from the System Engineering Office include TBS.

Configuration Management also includes the control of the content and revision of program specifications, plans, interface documents, and drawings, following document or drawing release. The Project Office will establish the CM System during Phase TBD.

The LISA Configuration Management Plan will detail the CM processes including the various boards and the responsibilities, and provides the processes, forms, and board chairmanship.

One centralized CM system will be used for the LISA Project

3.9.2 Configuration Control Board

The Configuration Control Board (CCB) controls and minimizes the impact of design changes and ensures that authorized changes are implemented efficiently. The CCB reviews all Configuration Change Requests (CCRs) written by development team engineers, and is the final authority for all changes. The CCB is chaired by a representative from the LISA Project Office, with the other members representing cost, schedule, Systems Engineering, CM, and *ad hoc* engineers. *Ad hoc* engineers are called in as needed to support evaluation of individual CCRs, depending on the topic.

3.10 COMMUNICATION

Given the complexity of the interactions of LISA, the diverse proximity of the team members, and challenging technical endeavors, open communication between all LISA members is essential for the success of the LISA mission.

3.10.1 Quarterly Technical Interface Meetings (TIM)

The System Engineering Office will conduct quarterly face-to-face meetings. These meetings are intended to bring GSFC, the Jet Propulsion Laboratory (JPL), and ESA together for technical discussions.

3.10.2 Science and Engineering Workshops

These workshops are held quarterly in order to bring the scientists and engineers together to discuss mission, system, and technical issues. These workshops ensure that the engineers are aware and understand the science objectives and the scientists are aware of the technical issues and activities.

3.10.3 Weekly Teleconferences

The System Engineering Office conducts a weekly telecon with ESA , JPL, and GSFC. The purpose of the telecons is to coordinate the engineering activities on a weekly basis between ESA and NASA.

3.10.4 Net Meeting

TBS

3.10.5 Project Web Site

TBS

3.10.6 LIST Meetings

The System Engineering Office also participates in the bi-annually LIST meetings. Participation in these meetings helps to ensure that system engineering understands the science objectives and ramifications of design decisions.

4.0 LISA DOCUMENTATION STRUCTURE

Need introduction paragraph

Figure 4-1. LISA Mission System Engineering Office Documentation Tree

Table 4-1. LISA Document Table

Document	Purpose/Content	Custodian	Signoff
Science Requirements	Defines basic science functionality. The requirements are stated in terms of prototypical astrophysical objects and their parameters.	Project or Mission Scientist	Project Scientist Mission Scientist ESA Project Scientist NASA and ESA PMs NASA Deputy PM
Level 1 Requirements	Serves as the top level for the requirements flow-down. It defines basic mission parameters, constraints, and programmatic boundaries. (e.g., top-level science and mission requirements, external agreement requirements, and NASA/ESA constraints.) The document will be updated as progress is made until the time it is signed.	Project Manager (PM) Mission System Engineering Manager (MSEM)	NASA Program Executive (HQ) NASA and ESA PMs NASA Deputy PM Project Scientist NASA and ESA Mission Scientists
Mission System Specification (MSS)	The MSS will be drafted after the Level 1 Requirements document is generated. The MSS will also contain top-level mission specifications and description of the mission, system, and interfaces between Level 3 components. The MSS will contain Level 2 mission functional and performance requirements, which when met by the system, will satisfy the Level 1 requirements and mission objectives. The MSS will contain all requirements that cross between Level 3 elements, including error allocations, control loops, etc. The MSS will include mission-level environmental requirements and orbit parameters. The MSS will provide top-level requirements for the lower-level documents and also contain a verification matrix describing how each requirement is verified. The MSS will be updated as progress is made until the time it is signed.	MSEM	NASA and ESA PMs NASA Deputy PM MSEM Project Scientist NASA and ESA Mission Scientists
Mission Architecture and Design	Describes the LISA system architecture at the element level, as allocated from the segments, including hardware and software for those elements.	MSEM	

Table 4-1. LISA Document Table (contd.)

Document	Purpose/Content	Custodian	Signoff
Operations Concept	Provides the functional model and associated operational scenarios upon which the model operates. Data flow diagrams, data dictionary, functional description, and operational scenarios are also included in this document.	MSEM	
Project Plan	Establishes the overall baseline for implementation as well as agreements among the Lead Center Director (LCD), Program Manager, Project Manager, and the involved NASA Center managers.		
Configuration Management Plan	Identifies the Configuration Management (CM) processes including the various boards and responsibilities, and provides the processes including the forms and board chairmanship.		
Risk Management Plan	Identifies the process to be used for the management risks to the definition and implementation of the mission, including technical, cost, schedule, and programmatic boundaries.	Risk Manager	
International Traffic in Arms Regulations (ITAR)	A handbook issued by the Society for International Affairs (document reference number 22 CFR 120-130), which lists the rules that apply to the export of mainly defense-related products and information including sensitive data and data products (i.e., may apply to laptop computers and other electronic devices).	N/A	
Integrated Modeling Plan	TBS	Integrated Modeling Manager	
Software Management Plan	Describes the functional, performance, and interface requirements of the software to be developed for the LISA sciencecraft system.	Software Architect	
Payload Functional Requirements	Defines the detailed functional requirements for the payload system and allocation of Level 3 requirements to payload subsystems. This document also will include a detailed description of the functionality of the payload and the required interfaces between payload and its subsystems.	Payload System Engineer	MSEM Payload Manager Payload SE
Laser Specification	Identifies the detailed laser and algorithm level specifications for the development of the laser and algorithms.		
Gravitational Sensor Specification	Identifies the detailed gravitational sensor and algorithm level specifications for the development of the gravitational sensor and		

	algorithms.		

Table 4-1. LISA Document Table (contd.)

Document	Purpose/Content	Custodian	Signoff
Optical Specification	Identifies the detailed optical and algorithm level specifications for the development of the optics and algorithms.		
Sciencecraft Functional Requirements	Contains Level 3 requirements for the sciencecraft, based on Level 2 mission requirements and Systems Operations Concept. It includes functional, performance, interface, and operational requirements at the segment level.	Spacecraft System Engineer	MSEM S/C Manager S/C SE
Command and Data Handling (C&DH) Specification	Establishes and describes in detail the performance, functional, interface, and design requirements necessary for developing the C&DH subsystem.		
Attitude and Control Specification	Establishes and describes in detail the performance, functional, interface, and design requirements necessary for developing the Attitude and Control subsystem.		
Communications Specification	Establishes and describes in detail the performance, functional, interface, and design requirements necessary for developing the Communications subsystem.		
Power Specification	Establishes and describes in detail the performance, functional, interface, and design requirements necessary for developing power for the entire LISA system.		
Mechanical Specification	Establishes and describes in detail the design requirements for the structure of the sciencecraft and the interface structures between the sciencecraft bus and payload.		
Thermal Control Specification	Establishes and describes in detail the design requirements for all temperature monitoring and control hardware for the sciencecraft bus and payload.		
Thruster Specification	Establishes and describes in detail the performance, functional, interface, and design requirements for developing the thrusters.		
Ground System Functional Requirements	Establishes and describes in detail the performance, functional, and interface requirements necessary for developing the LISA ground system.		
System Engineering Management Plan	Describes the activities to be performed by NASA's GSFC System Engineering Office in support of the LISA Project's mission	MSEM	

(SEMP)	formulation. The SEMP will be updated once the Formulation Phase has been completed and transitioned to the Implementation Phase.		

Table 4-1. LISA Document Table (contd.)

Document	Purpose/Content	Custodian	Signoff
System Verification Plan	Provides a system-level verification plan, identifies the integration, activities, sequencing, test phasing, and tool utilization.	System Architect	
Integration and Test Plan	Describes the implementation plan for the system-level integration, including the verification methods/criteria, test sequencing, and mapping to the mission-level requirements.		
Comprehensive Performance Test Plan	TBS		
Thermal Vacuum Test Plan	Describes what is to be tested, the testing equipment or facilities, the approach to the testing, and step-by-step operations and the expected results.		
Vibration Test Plan	Describes what is to be tested, the testing equipment or facilities, the approach to the testing, and step-by-step operations and the expected results.		
EMI/ EMC Test Plan	Describes the test objectives, requirements, and methods to verify the electromagnetic compatibility of the payload and all sciencecraft components.		
Performance Assurance Plan	Establishes hardware and software product assurance requirements with respect to safety, reliability, and quality for the design, development, acquisition, test, and operation of the LISA system.		
Mission Assurance Requirements (MAR) Plan	Presents the safety and mission assurance (SMA) requirements that will be necessary for the LISA Program.		
Contamination Control Plan	Defines the contamination control requirements for the LISA sciencecraft during fabrication, assembly, integration, test, and launch operations. It also specifies the verification approach to ensure that the requirements are met.		
Electrostatic Discharge (ESD) Control Plan	Defines the electrostatic control requirements for the LISA sciencecraft during fabrication, assembly, integration, test, and launch operations. It also specifies the verification approach to ensure that the requirements are met.		

Launch Vehicle Interface Control Document	Identifies the sciencecraft systems requirements for use in launch vehicle studies, preliminary design, and detailed design.		

Table 4-1. LISA Document Table (contd.)

Document	Purpose/Content	Custodian	Signoff
Launch Safety Plan	In compliance with the Range Safety requirements, the plan covers range safety, pad safety, and flight termination.		
Launch Site Support Plan	TBS		

5.0 INTEGRATED DESIGN TEAM AND WORKING GROUPS

This section describes the LISA Integrated Design Team and working groups that will execute the development of the system engineering products (see Figure 5-1).

5.1 INTEGRATED DESIGN TEAM

LISA is not like a traditional NASA project and presents many system engineering challenges. The following issues contribute to these challenges:

- Complex interactions between subsystems
- The sciencecraft and payload are tightly coupled and indistinguishable
- Subtle interactions inside subsystems that affect the system
- System engineering activities are occurring across the globe

To ensure the success of LISA, the system perspective is essential throughout all phases of the mission. Each engineer must be knowledgeable of the effects produced by their subsystem on the overall system. Managing these interactions is a great challenge to the Systems Engineering Office.

To meet this challenge, the System Engineering Office will set up an IDT. The IDT will orchestrate the evolution of the LISA design throughout all phases of the mission. During the Formulation phase, the IDT will develop and define the architecture; make key architecture decisions; develop and define the operations concept; define, conduct, and lead trade studies; and verify the architecture and operations concept against the requirements.

The Integrated Design team will also provide oversight for the Software Architecture Working Group, Modeling Working Group, and the Integration and Test (I&T) Working Group and will coordinate science related issues with the LISA International Science Team.

The Mission System Engineering Manager (MSEM) chairs the IDT. It is comprised of engineers and scientists from ESA, GSFC, and JPL. Membership, in addition to the MSEM, includes the Project Scientist, Mission Scientist, Payload SE, Spacecraft SE, and Ground SE. This group will have no more than eight members. Other working groups will be formed per the direction of the Integrated Design Team. The working groups will address specific issues. Key scientists and engineers will staff the working groups as appropriate.

5.2 SYSTEM ENGINEERING WORKING GROUPS

The IDT provides oversight for the Requirements Analysis Working Group, Software Architecture Working Group, Modeling Working Group, and the I&T Working Group and will coordinate science related issues with the LISA International Science Team. The working groups will be formed and dismantled as needed.

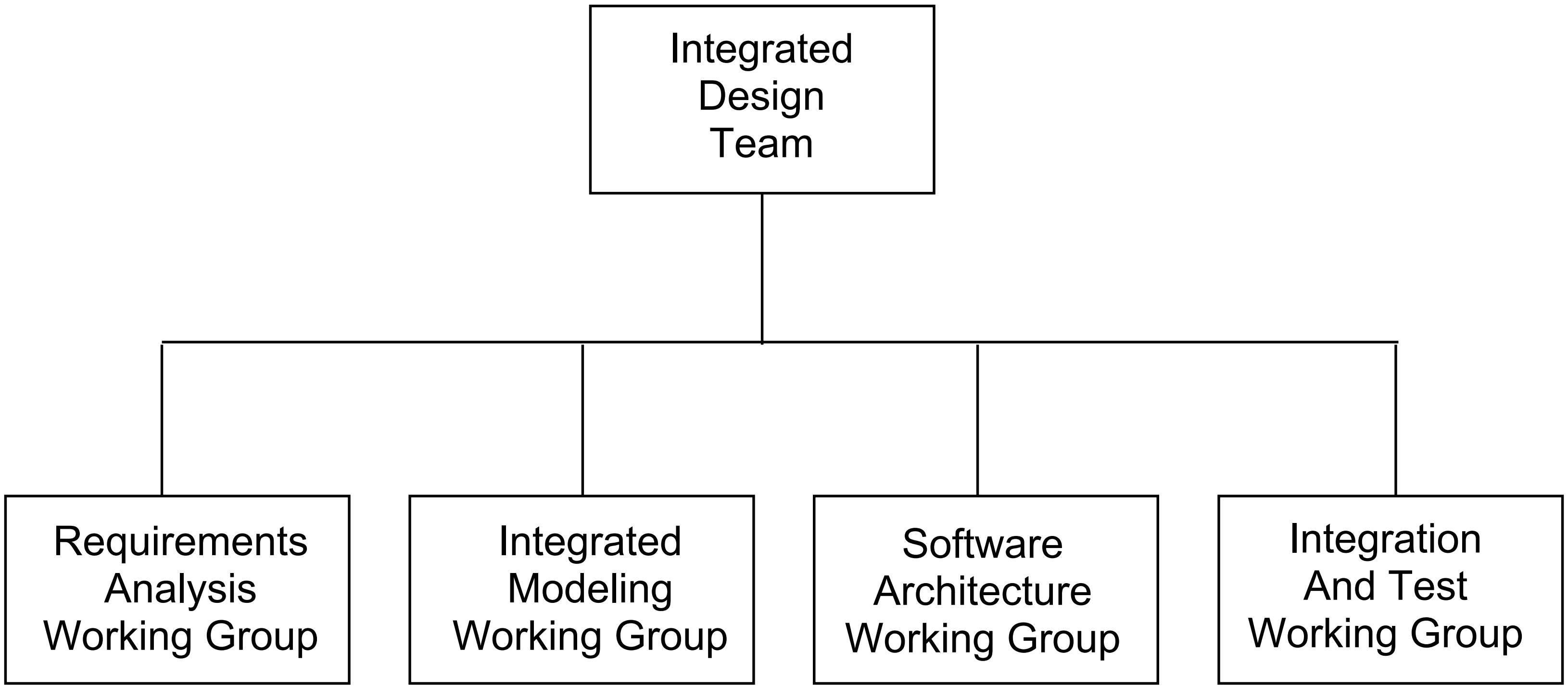

Figure 5-1. LISA Working Groups

5.2.1 Requirements Analysis Working Group

To be supplied

5.2.2 Software Architecture Working Group

To be supplied

5.2.3 Modeling Working Group

To be supplied

5.2.4 Integration and Test Working Group

To be supplied

6.0 SYSTEM ENGINEERING MANAGEMENT

6.1 SYSTEM ENGINEERING OFFICE

The System Engineering Office is organizationally located in the LISA Project. The organization chart for the LISA Project is available on the LISA Project web site at: http://lisa.gsfc.nasa.gov/Management/Mgmt.html

The System Engineering Office is responsible for ensuring the technical cohesiveness of all individual project elements. It is responsible for establishing the overall framework and procedures for management of the LISA technical requirements, design process, and the verification process, and for orchestrating the evolution of the design through all phases of the mission. It is also responsible for centralizing a documentation system where all project documents will be kept.

6.2 ROLES AND RESPONSIBILITIES

The LISA System Engineering Office organization chart, shown in Figure 6-1, identifies each position and corresponding area of responsibility. Additionally, the lines of reporting and authority are depicted on the organization chart. The roles and responsibilities for each major element of the System Engineering Office organization chart are defined below.

6.2.1 Mission System Engineering Manager

The MSEM is the leader of the LISA System Engineering Team and is responsible for the overall management and success of the LISA System Engineering. The MSEM is responsible for facilitating the resolution of issues between segments as well as coordinating issues/progress with Project Management. The MSEM is the chair of the Integrated Design Team. He/she is responsible for leading and coordinating the definition of the system architecture and operations concept. The MSEM is responsible for leading the Requirements Working Group and for maintaining the Level 1 Requirements Document, the Mission System Specification (Level 2 Requirements) and the SEMP. He/she is responsible for developing the documentation hierarchy, including signoff structure for documents.

6.2.2 Deputy Mission System Engineering Manager

The Deputy Mission System Engineering Manager reports to the MSEM and is responsible for supporting her in all her tasks and represents her whenever she is not available.

6.2.3 System Architect

He/she is responsible for maintaining the Operations Concept document, Mission Architect and Design Specification, Block Diagram, and Verification Plan. In addition, he/she maintains error budgets, performance budgets and margin allocations for system resources. He/she generates and maintains some ICDs.

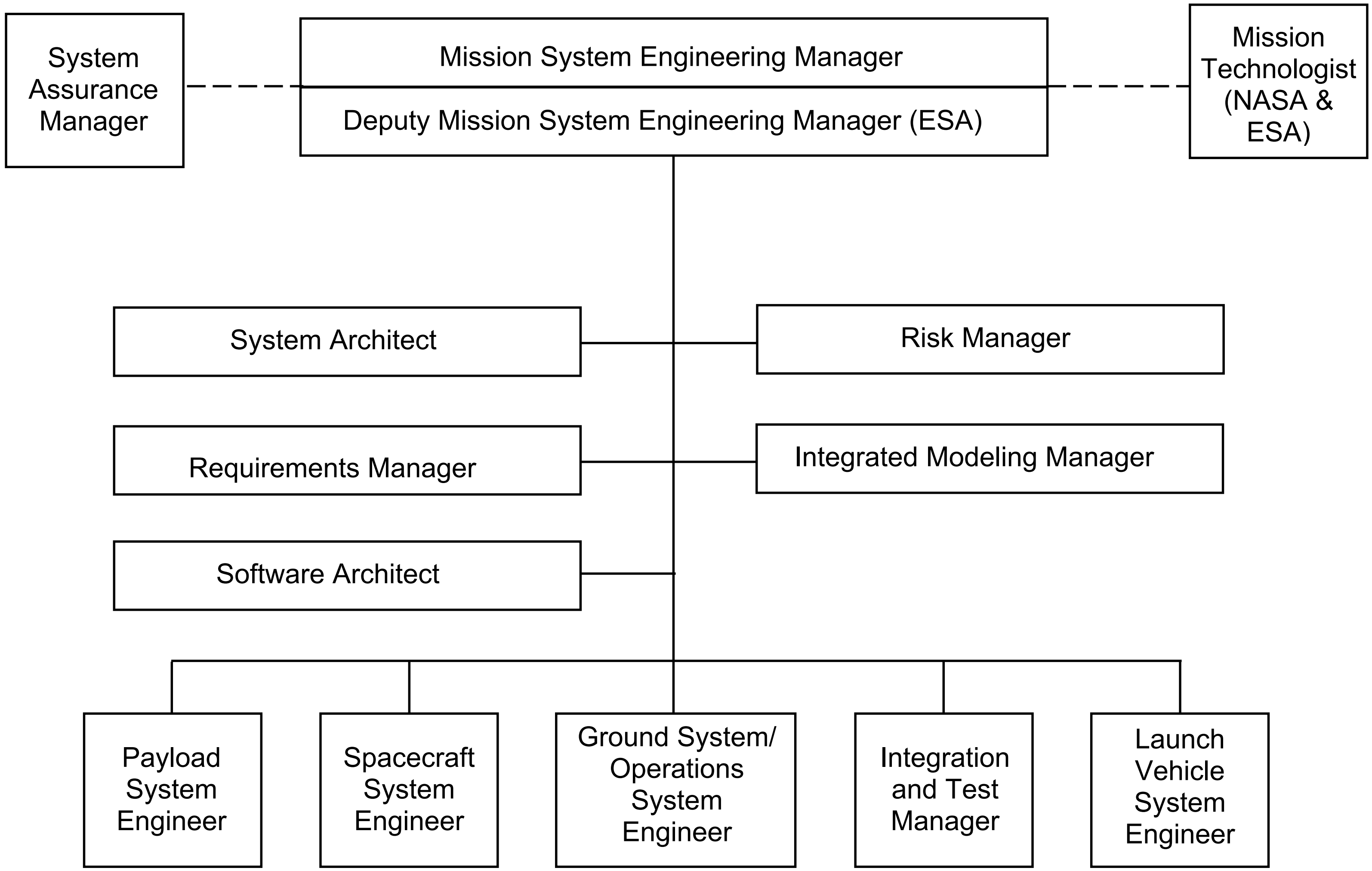

Figure 6-1. LISA System Engineering Office Organization Chart

6.2.4 Requirements Manager

The Requirements Manager is responsible for providing guidelines and procedures for LISA technical requirements flow-down. He/she establishes the procedures and tools to be used for requirements tracking as well as Configuration Management. He/she is also responsible for maintaining the system for tracking LISA requirements.

6.2.5 Software Architect

The Software Architect is responsible for defining overall software architecture strategy and is responsible for writing guidelines and procedures pertaining to software. He/she also coordinates all Independent Verification and Validation (IV&V) activities.

6.2.6 Integrated Modeling Manager

The Integrated Modeling Manager is responsible for leading and coordinating the development of the LISA End-to-End Integrated Model.

6.2.7 Mission Technologists

Both the NASA and ESA Mission Technologists are responsible for the technology development effort.

6.2.8 Risk Manager

The Risk Manager is responsible for developing the Risk Management Plan. He/she is also responsible for coordinating all risk management activities, including documentation, tracking, and mitigation plans.

6.2.9 System Assurance Manager

The System Assurance Manager (SAM) is responsible for assuring the performance reliability of all flight and ground system segments of the LISA mission.

6.2.10 Spacecraft System Engineer

The Spacecraft System Engineer is a member of the Integrated Design Team and will work with the IDT to allocate requirements from the LISA MSS to the sciencecraft subsystems. He is also responsible for generating ICDs internal to the agency and the sciencecraft.

6.2.11 Payload System Engineer

The Payload System Engineer is a member of the Integrated Design Team. He/she will work with the IDT to develop the payload architecture in response to the higher level requirements and specifications. He/she is responsible for allocating requirements from the MSS to the Payload Requirements document and payload subsystems. He/she is also responsible for maintaining all payload-specific documents in accordance with procedures and constraints established the by System Engineering Office. He/she maintains the payload resource budgets as part of the centralized resource budget established and maintained by the System Engineering Office. He/she is also responsible for generating and maintaining the Payload Functional Requirements Document. He/she manages the interfaces between payload elements while working within the Integrated Design Team to ensure that all higher-level interface requirements are satisfied.

6.2.12 Ground System/Operations System Engineer

The Ground System/Operations System Engineer is responsible for supporting the Software Architect in the development of the system architecture.

6.2.13 Integration and Test Manager

The I&T Manager is responsible for planning and implementing the End-to-End I&T activities, including final acceptance.

6.2.14 Launch Vehicle System Engineer

The Launch Vehicle System Engineer is responsible for interfacing with the launch site, which performs procurement, budgeting, planning and scheduling, and other actions necessary for designing, developing, fabricating, testing, modifying, launching, and tracking the launch vehicle through the orbit transfer trajectory insertion.

ACRONYMS

C&DH	Communications and Data Handling
CDR	Critical Design Review
CM	Configuration Management
DSN	Deep Space Network
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESA	European Space Agency
FAD	Formulation Authorization Document
FRR	Flight Readiness Review
FTR	Final Technical Report
GPG	Goddard Procedure and Guideline
GSFC	Goddard Space Flight Center
GSE	Ground Support Equipment
HQ	Headquarters
I&T	Integration and Test
ICD	Interface Control Document
IDT	Integrated Design Team
IV&V	Independent Verification and Validation
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
LCD	Lead Center Director
LISA	Laser Interferometer Space Antenna
LRR	Launch Readiness Review
MAR	Mission Assurance Requirements
MCR	Mission Concept Review
MOR	Mission Operations Review
MRR	Mission Requirements Review
MSE	Mission Systems Engineer
MSEM	Mission System Engineering Manager
MSS	Mission System Specification
NASA	National Aeronautics and Space Administration

ACRONYMS (cont.)

PDR	Preliminary Design Review
PER	Pre-Environmental Review
PI	Principal Investigator
PM	Project Manager
PSR	Pre-Ship Review
SAM	System Assurance Manager
SCR	System Concept Review
SE	System Engineer
SEMP	System Engineering Management Plan
SMA	Safety and Mission Assurance
SRR	System Requirements Review
TBD	To Be Determined
TBS	To Be Scheduled
TIM	Technical Interchange Meeting
TT&C	Tracking, Telemetry, and Command