INFORMATION SYSTEM LIFE-CYCLE

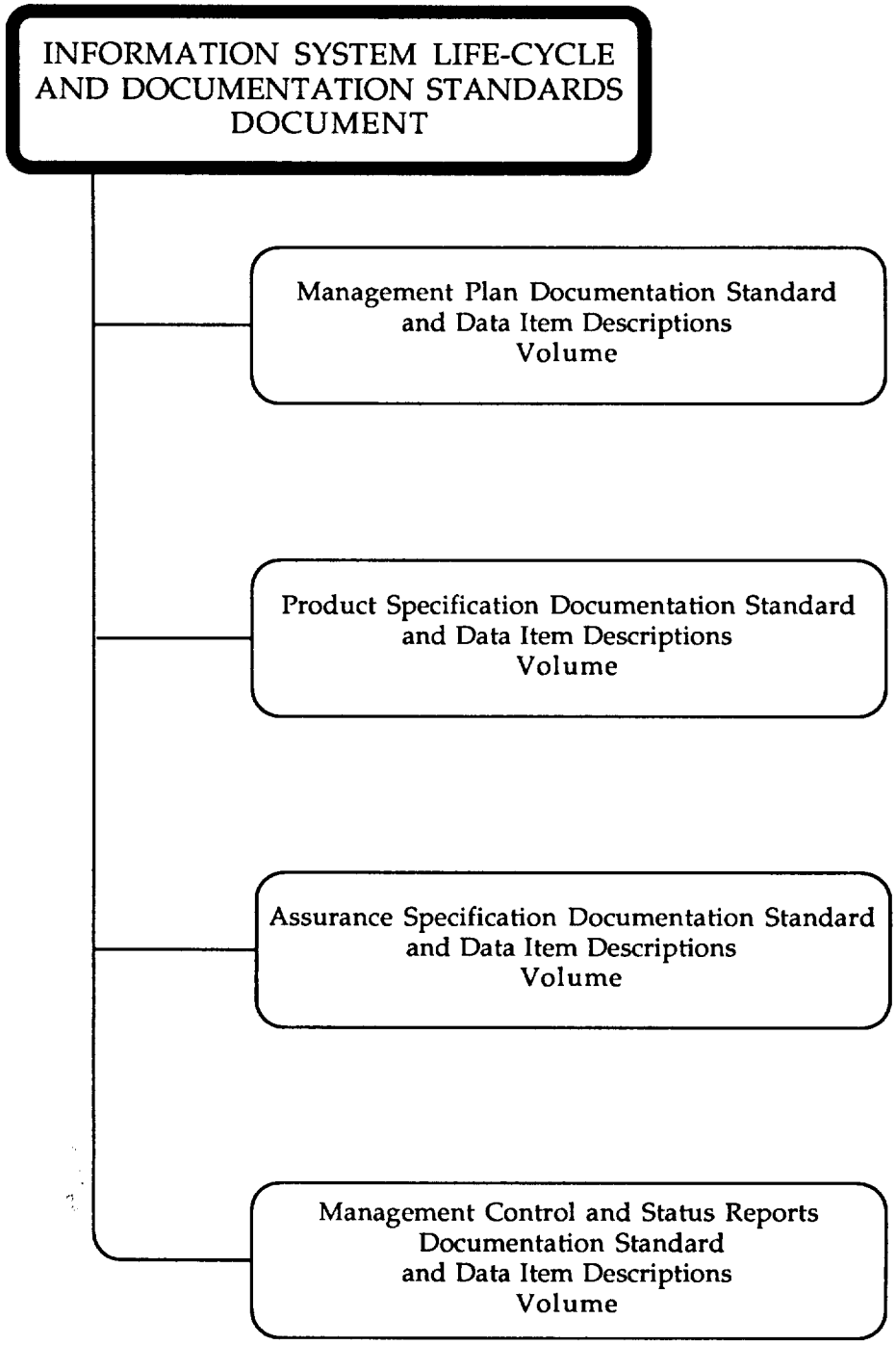
AND

DOCUMENTATION STANDARDS

Release 4.3

2/28/89

NASA
Office of Safety, Reliability, Maintainability, and Quality Assurance
Software Management and Assurance Program (SMAP)
Washington, DC



ACKNOWLEDGEMENTS

This document incorporates the extensive work of Dr. E. David Callender and Ms. Jody Steinbacher in specifying the documentation standards for information systems and their components. Their contributions are reflected especially in the concept and definition of the information system, the identification of the major categories of documentation, the definition and application of the roll-out concept, the specification of documentation frameworks, the concept of nested life-cycles for components of information systems, and the description of the relationship between information system acquirers and providers.

They have advanced the state-of-the-art for information systems life-cycle management by establishing simplifying principles for identifying needed documentation units to fit a particular system's environment and organization.

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INFORMATION SYSTEM LIFE-CYCLE AND DOCUMENTATION STANDARDS

1.0 INTRODUCTION

1.1 Identification of Document

The Software Management and Assurance Program (SMAP) Information System Life-Cycle and Documentation Standards Document describes the Version 4 standard information system life-cycle in terms of processes, products, and reviews. The description of the products includes the detailed documentation standards.

1.2 Scope of Document

The standards in this document set can be applied to the life-cycle and documentation of all NASA information systems. An "information system" is a software-intensive system; it is any combination of software, hardware, and operational procedures required to process, store, or transmit data. This document includes standards for life-cycle and documentation for information systems and their software, hardware, and operational procedures components.

This standard is limited to the specification of a life-cycle model and documentation content. It does not define specific management, engineering, or assurance standards.

Use of the SMAP Information System Life-Cycle and Documentation Standards is determined on a program/project basis. Hence, the application, tool support, and enforcement of these standards is the responsibility of the program/project management.

1.3 Purpose and Objectives of Document

The purpose of this document is to define a standard life-cycle model and content for associated documentation. These standards provide a framework to allow consistency across the agency and also visibility into the completeness of the information recorded.

1.4 Document Status and Schedule

Release 4.2C was the first complete release for Version 4 of the Information System Life-Cycle and Documentation Standards document. All five volumes of the document underwent a SMAP and agency review. Release 4.3 is an update to Release 4.2C based on the approved RIDs from this review. The RID review board determined that change bars will not be used to show the differences between Releases 4.2C and 4.3, as 4.3 is the first baselined release of the Version 4 standards.

1.5 Document Organization and Roll-Out

This document is organized into ten sections, as follows:

- Section 1 defines the scope and purpose of the document
- Section 2 lists applicable documents
- Section 3 provides an overview and background of the information system life-cycle and documentation standards
- Section 4 contains the standards. The Life-Cycle Standard describes the information system and component life-cycles in detail, including the rules for their use. The detailed documentation standards related to the life-cycle have been rolled-out into separate volumes:
  - Management Plan Documentation Standard and Data Item Descriptions
  - Product Specification Documentation Standard and Data Item Descriptions
  - Assurance Specification Documentation Standard and Data Item Descriptions
  - Management Control and Status Reports Documentation Standard and Data Item Descriptions
- Section 5 discusses the application and support of the standards with emphasis on guidelines for use of the life-cycle. (Guidelines for use of the document standards are contained in the appropriate documentation standard volume.)
- Section 6 contains suggestions on the assurance and enforcement of the standards
- Sections 7 and 8 define the abbreviations, acronyms, and significant terms used throughout the standards
- Sections 9 and 10 are available for notes and appendices

2.0 RELATED DOCUMENTATION

2.1 Parent Documents

None.

2.2 Applicable Documents

The following volumes/documents are referenced herein and are directly applicable to this document:

1) Management Plan Documentation Standard and Data Item Descriptions (DID) Volume of the Information System Life-Cycle and Documentation Standards, Release 4.3, 2/28/89. Washington: NASA Office of Safety, Reliability, Maintainability, and Quality Assurance.

2) Product Specification Documentation Standard and Data Item Descriptions (DID) Volume of the Information System Life-Cycle and Documentation Standards, Release 4.3, 2/28/89. Washington: NASA Office of Safety, Reliability, Maintainability, and Quality Assurance.

3) Assurance Specification Documentation Standard and Data Item Descriptions (DID) Volume of the Information System Life-Cycle and Documentation Standards, Release 4.3, 2/28/89. Washington: NASA Office of Safety, Reliability, Maintainability, and Quality Assurance.

4) Management Control and Status Reports Documentation Standard and Data Item Descriptions (DID) Volume of the Information System Life-Cycle and Documentation Standards, Release 4.3, 2/28/89. Washington: NASA Office of Safety, Reliability, Maintainability, and Quality Assurance.

5) IEEE Standard Glossary of Software Engineering Terminology. ANSI/IEEE Std 729-1983. New York: Institute of Electrical and Electronic Engineers, Inc.

2.3 Information Documents

The following documents, although not directly applicable, are referenced for historical continuity:

1) Military Standard for Defense System Software Development, DoD-STD-2167, 4 June 1985, and DoD-STD-2167A, 27 October 1987.

2) NASA Software Data Item Descriptions, Version 3, November 1986. Washington: NASA Office of Safety, Reliability,

Maintainability, and Quality Assurance. (Additional Data Item Descriptions were published as Versions 3.1 - 3.5 in 1987.)

3) Space Station Program Software Management Policies, November 1986.

4) Chart. NASA Information System Life-Cycle Inter-relationships: A Phased-Delivery Model. December 1987. Washington: NASA Office of Safety, Reliability, Maintainability, and Quality Assurance.

5) Chart. NASA Software Acquisition Life-Cycle. Version 3.0, 10/15/86. Washington: NASA Office of Safety, Reliability, Maintainability, and Quality Assurance.

6) Information Processing Resources Management, NHB 2410.1D, April 1985.

7) Management of Federal Information Resources, OMB Circular No. A-130, 12 December 1985.

8) System Safety Engineering Methodologies, NHB 1700.1(V7), March 1988.

9) Assuring the Security and Integrity of NASA Automated Information Resources, NMI 2410.7A, Draft Rev. 3/14/88.

3.0 OVERVIEW OF THE LIFE-CYCLE AND DOCUMENTATION STANDARDS

3.1 Scope of the Life-Cycle and Documentation Standards

A life-cycle is a series of steps, called phases, used to coordinate and control the development and sustaining engineering of an information system or hardware, software, or operational procedures component. Each phase consists of a set of activities to accomplish the goals of the phase and of associated products of those activities. A review, called a phase transition review, is defined as a mechanism for determining when to transition from one phase to the next.

The SMAP Information System Life-Cycle and Documentation Standards are applicable to all NASA information systems and hardware, software, and operational procedures components.

The selection, adaptation, and enforcement of these SMAP standards is the responsibility of the cognizant program/project manager.

It is important to note that these life-cycle and documentation standards are not management, technical and engineering, or assurance standards. However, the life-cycle is defined in terms of management, engineering, and assurance activities to be conducted in each phase. The documentation standards provide the organization for recording the results of these management, engineering, and assurance activities.

3.2 Rationale for the Life-Cycle and Documentation Standards

The rationale for the life-cycle definition and documentation structures presented in this standard is to provide:

1) A model for organizing and executing management, engineering, and assurance activities. This model supports sound management, engineering, and assurance practices, and NASA standards regarding these activities.

2) A method of organizing information about life-cycle activities such that users, authors, and reviewers of documentation know where to find or place each item of information.

3) Uniformity of format and content of documentation throughout NASA programs/projects for ease of use and understanding.

4) A reference document which can be used as a checklist during document reviews.

These standards were derived from Version 3 of the SMAP Data Item

Descriptions (DIDs) based on industry feedback to: 1) provide relationships between different pieces of information (DIDs); 2) supply a tailoring mechanism for the DIDs; and 3) present a system perspective. The SMAP life-cycle and documentation standards are based upon the assumption that it is the responsibility of program/project management to:

1) Select, adapt, and enforce the life-cycle model for the program/ project and for each information system and major component within the program/project.

2) Select what information is to be formally recorded, adapt the documentation standards for each information system and component of the program/project, and enforce the use of the specified adaptation.

3.3 Interface with Other Standards

At the time of the publication of Release 4.3 of the SMAP Information System Life-Cycle and Documentation Standards, there are no other SMAP information system standards. However, these life-cycle and documentation standards have been designed to be supportive of a broad range of potential management, technical and engineering, and assurance standards including existing detailed standards such as NASA and NASA Center technical hardware standards.

3.4 Definition of Major Concepts and Terms

Prior to presenting the life-cycle and documentation standards, it is essential to define basic terminology and concepts included in these standards.

The acquirer is the organization obtaining (acquiring) an information system or component. Providers are organizations performing a function or providing a capability to the acquirer.

An information system is composed of hardware, software, and operational procedures components required to process, store, and/or transmit data. See Figure 3-1. Within the context of this standard, an information system is a software-intensive system.

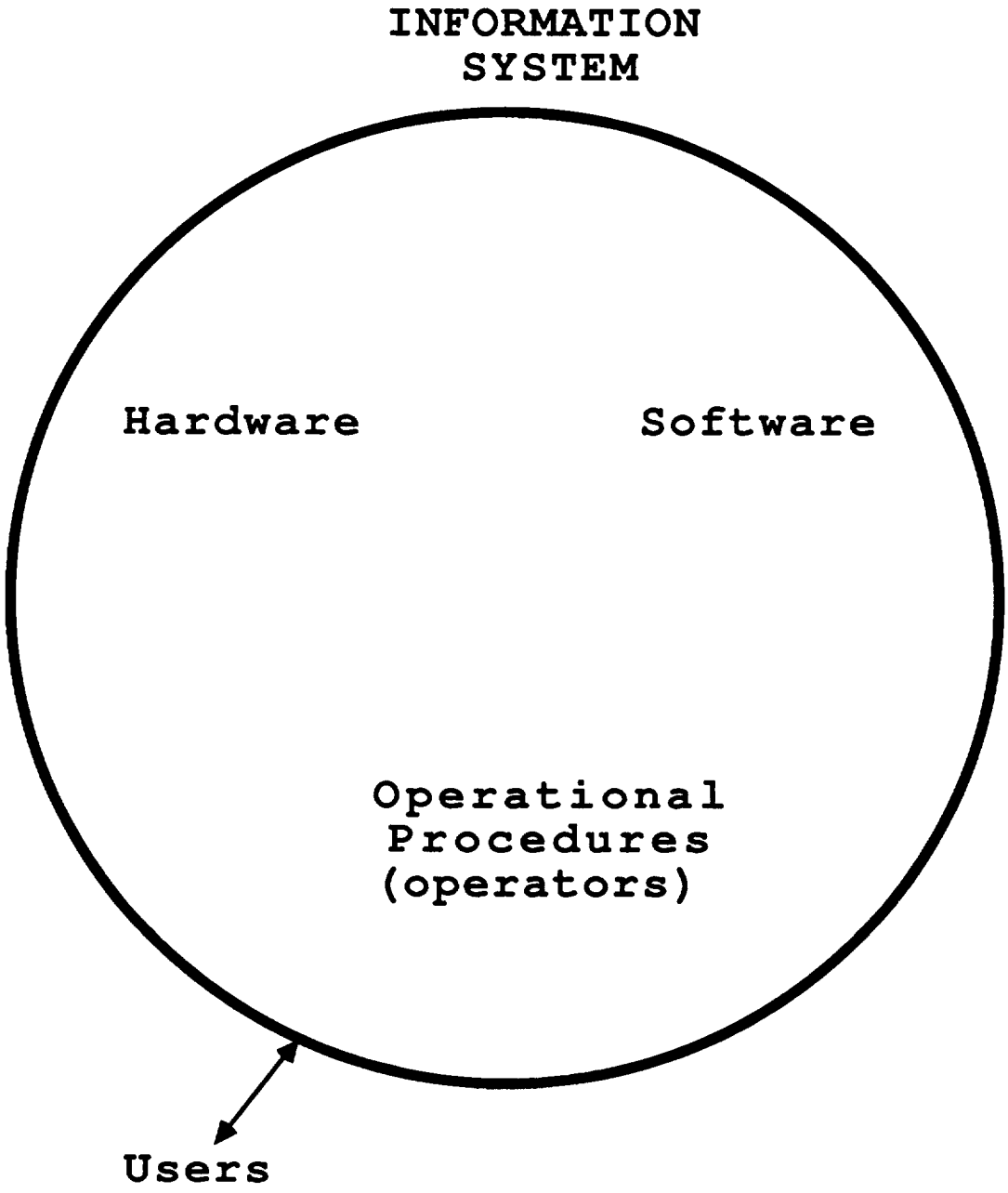

Figure 3-1. An Information System and Its Components.

The operational procedures are the manual procedures or processes (conducted by the operator of the system) that are an integral part of an information system's operational capability provided to the users. During system design, decisions related to automated versus manual processes, and hardware versus software (i.e., allocation of requirements to the various components) are made.

Within this definition, then, an "operator" (i.e., someone executing the operational procedures) is internal to the information system and a user is external to the information system. That is, the user utilizes the capabilities of the information system in performing a task. "Operators," executing the operational procedures, work in conjunction with the hardware and software to provide the operational capabilities of an information system to the users.

The life-cycle and documentation standards are supportive of system decomposition concepts. During design of an information system, the system may be decomposed into another level of information systems (referred to as subsystems) or into software, hardware, and operational procedures components. During the design of a component, it may be decomposed into another level of like components (or subcomponents), or it may proceed into detailed design and implementation.

An example of an information system decomposition tree depicting several levels of decomposition is presented in Figure 3-2.

A separate life-cycle is instantiated for each node in an information system's decomposition tree. The result is parallel life-cycles as depicted in Figure 3-3. The life-cycles of a node and its subordinate nodes inter-relate in terms of schedules, milestones, and products to be delivered from the subordinate nodes for review and approval. Further discussion and guidelines concerning decomposition and life-cycle adaptations are presented in Section 5 of this document.

When reading or applying these life-cycle and documentation standards, it is important to recognize that the position of the node in the information system decomposition tree affects the relationships, decisions, and application of these standards.

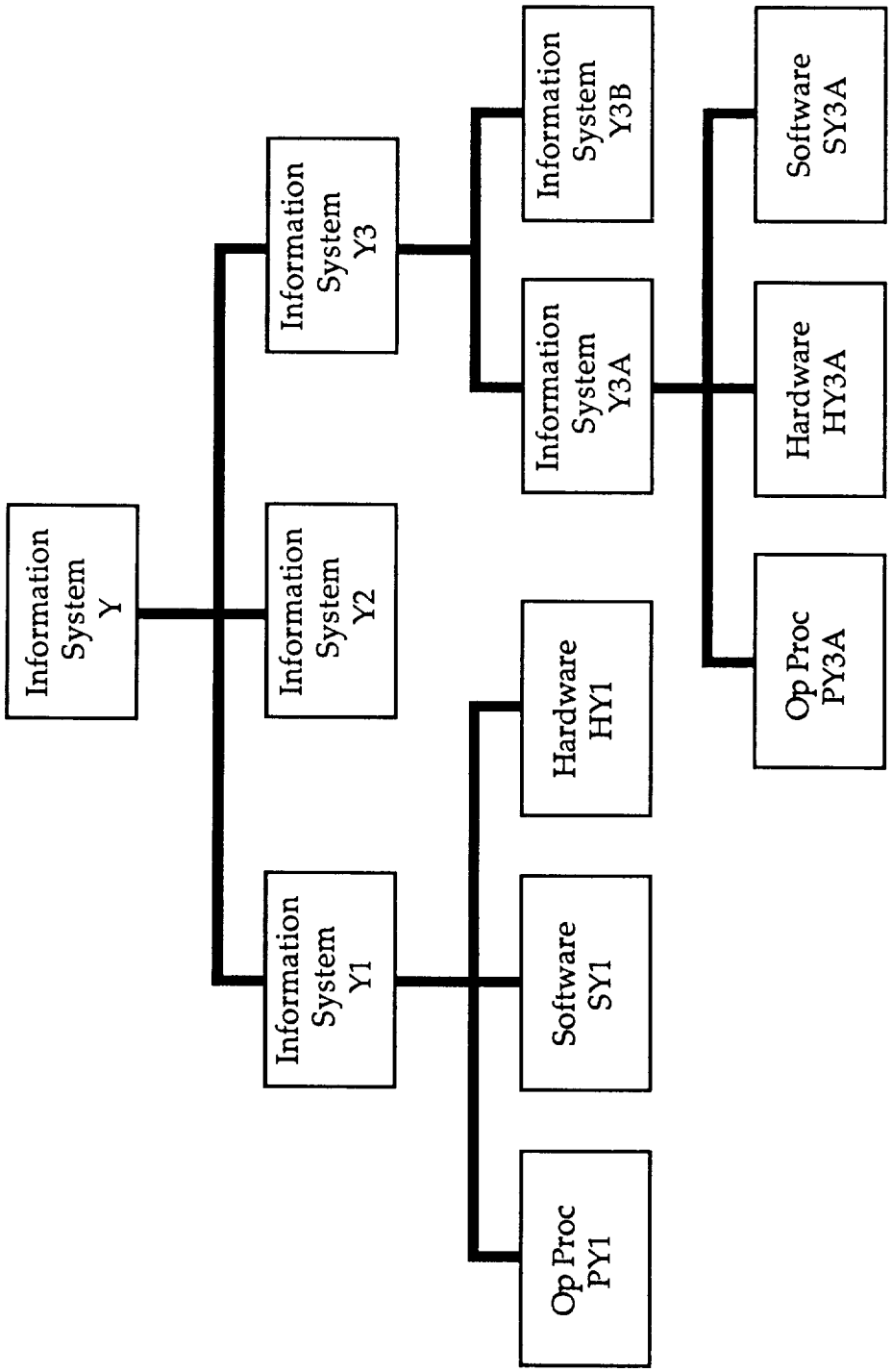

Figure 3-2. Example of an Information System Decomposition Tree.

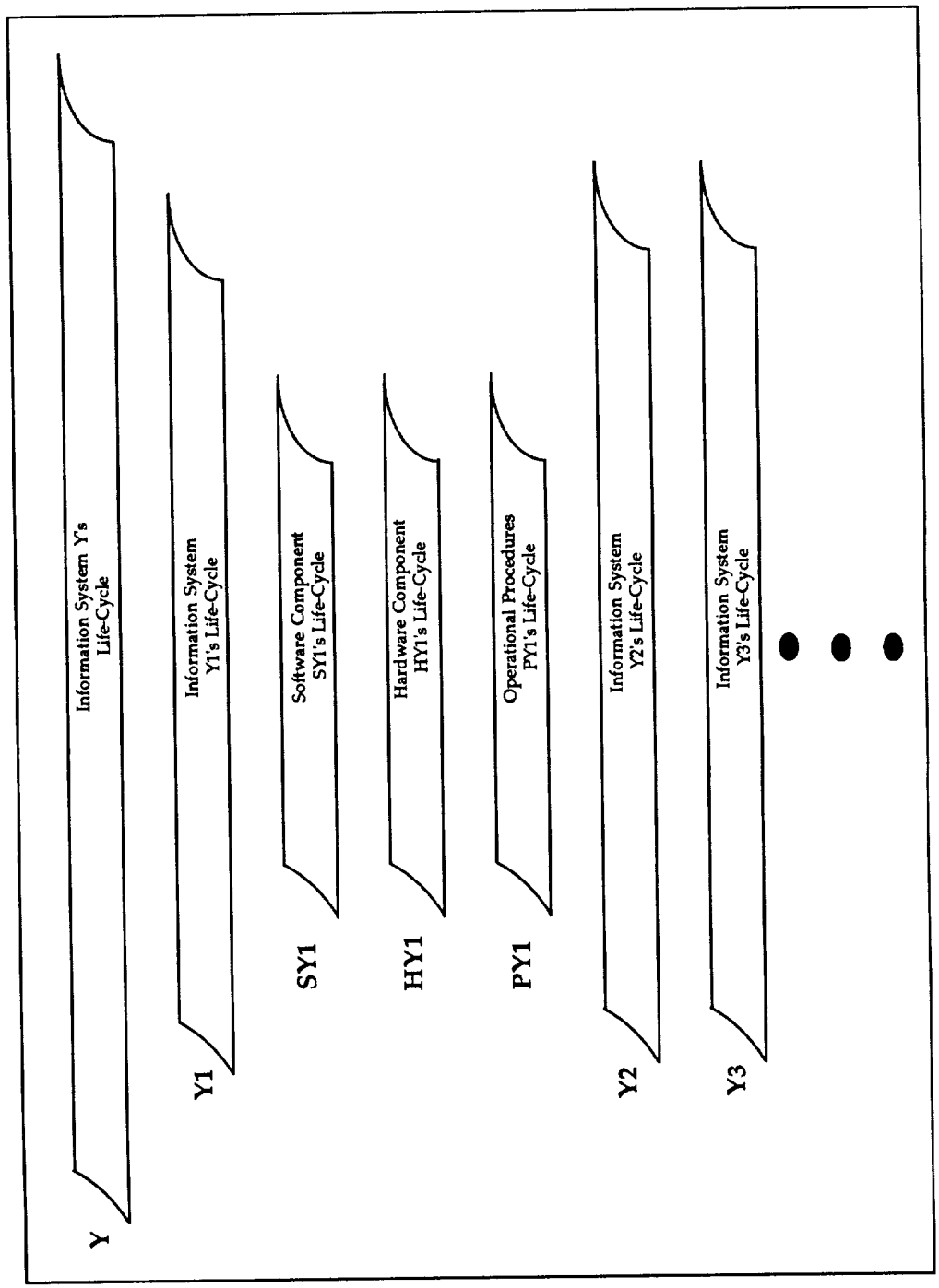

Figure 3-3. Information System Tree Life-Cycle.

4.0 THE LIFE-CYCLE AND DOCUMENTATION STANDARDS

4.1 Life-Cycle and Documentation Introduction

Each information system and component life-cycle consists of the following phases:

- Concept and Initiation: Includes evaluating the feasibility of the proposed information system or component, developing the management strategy and constraints, and defining the information system or component concept
- Requirements: Includes defining the development process and assurance strategies, and determining the technical requirements for an information system or component
- Design: Includes designing an information system or component and allocating the requirements to design elements
- Implementation [Coordination]: Includes coordinating and monitoring the implementation of the (next lower level) subsystems or components, or the actual implementation of a component
- Integration and Test: Includes integrating the (next lower level) subsystems or components or the component units, and integration testing
- Acceptance and Delivery: Includes validating that the delivered information system or component meets the technical and user's requirements
- Sustaining Engineering and Operations: Includes sustaining the operational capabilities of the information system or component, including repairs and upgrades within the context of the original concept of the system or component

The basic life-cycle model for an information system is depicted in Figure 4-1. The component life-cycles are defined in terms of variations from the information system life-cycle as illustrated in Figure 4-2.

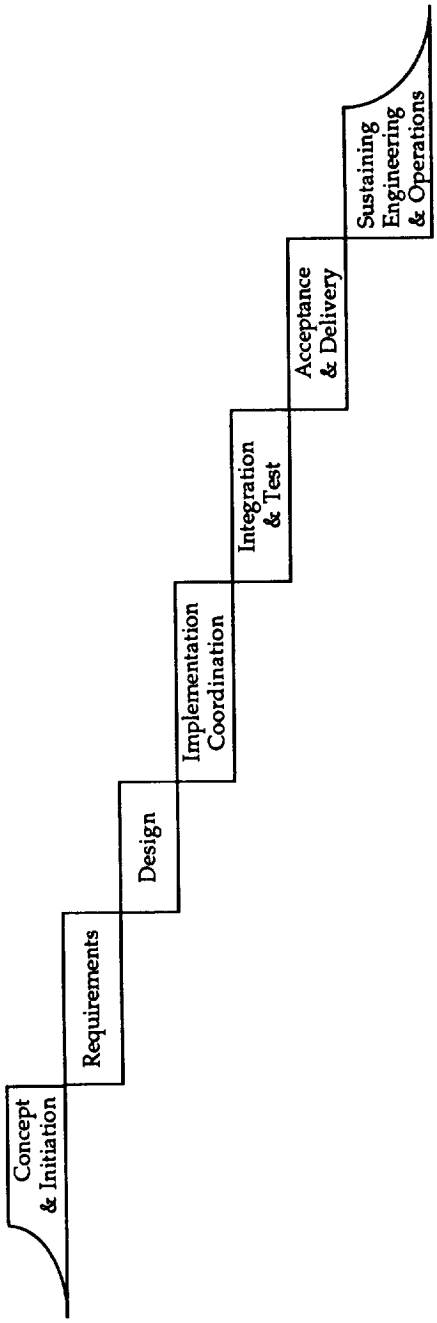

Figure 4-1. Information System Life-Cycle

Information System	Software	Hardware	Operational Procedure
Concept & Initiation	Same	Same	Same
Requirements	Same	Same	Same
Design	Architectural Design Detailed Design	Architectural Design Detailed Design	Design
Implementation Coordination	Implementation	Fabrication	Implementation
Integration & Test	Same	Same	Training & Evaluation
Acceptance & Delivery	Same	Same	
Sustaining Engineering	(support)	(support)	(support)

Figure 4-2. Component Life-Cycle Phase Variations.

Section 4.2 presents in detail the information system life-cycle model and Section 4.3 presents the software life-cycle model. Sections 4.4 and 4.5 present the hardware and operational procedures life-cycle models as variations from the information system model. Each model is presented by life-cycle phase. The phase is described in terms of its activities, products, and the phase transition review.

The activities for each phase are defined in terms of management, engineering, and assurance activities:

a) Management activities include all planning activities and the tracking and modification of the plans based on status, metric, and other feedback reports.

b) Engineering activities include the actual concept definition, requirements analysis, design, and implementation activities.

c) Assurance includes quality assurance, testing, quality engineering assurance, safety assurance, security and privacy assurance, verification and validation, and certification of both the products and processes. Assurance activities include the definition of specifications, procedures, criteria, and test and other evaluation expectations; the actual conduct of an assurance function such as a test or review; and the analysis of the results.

The documentation products for each life-cycle instantiation consist of a four-document set (see Section 4.6 for more details). The documentation set includes:

- A management plan
- A product specification
- An assurance specification
- A management control and status reports document

All planning activities are documented in the appropriate sections of the management plan. All engineering activities are documented in the appropriate sections of the product specification. All assurance (technical) activities are documented in the appropriate sections of the assurance specification.

The management control and status reports document is intended to provide a logical home for all reports. In general, these are management (status and performance), engineering (change request), and assurance (review) reports submitted to management as feedback on plans, processes, schedules, etc.

All documentation products of the life-cycle phases are specified in terms of content for a section of one of these four documents.

Specific details concerning the format, content, and organization of documentation is presented in Section 4.6.

A phase transition review is a major assurance activity that is conducted at the end of a phase to assure the products of that phase and to determine the readiness to proceed to the next phase. Further discussion of these reviews is presented in Section 4.7.

The life-cycles presented are models. It is assumed that they will be adapted for a specific information system or component by the cognizant management. Guidelines for common adaptations such as incremental development, phased delivery, and evolutionary acquisition, are presented in Section 5.1. (See the Glossary for definition of these terms.)

In addition, the life-cycle model does not assign responsibilities. The life-cycle model defines basic activities which are to be conducted and products to be generated or updated within a particular life-cycle phase. It is the responsibility of the information system or component management to assign specific responsibility for activities and document such assignment in the management plan.

The actual rules governing the use of this standard are presented in Section 4.8.

4.2 Information System Life-Cycle Definition

The information system life-cycle consists of the following phases:

- Information System Concept and Initiation
- Information System Requirements
- Information System Design
- Information System Implementation Coordination
- Information System Integration and Test
- Information System Acceptance and Delivery
- Information System Sustaining Engineering and Operations

This life-cycle is instantiated for each information system in the system decomposition tree.

4.2.1 INFORMATION SYSTEM CONCEPT AND INITIATION PHASE

The objectives of the Information System Concept and Initiation Phase are to evaluate the feasibility of the proposed information system, compile the user requirements, define the information system concept and scope, define the assurance strategy, and develop the management strategy and constraints for development of the information system.

4.2.1.1 Management Activities

Management planning begins in this phase by defining both the activities and structure of the organization obtaining the system (called the acquirer), and the development and assurance process requirements. Development process requirements definition includes procurement strategy decisions, life-cycle requirements and constraints, engineering standards and constraints, delivery requirements, and tracking and control mechanisms. Assurance process requirements definition includes criticality classification of the information system, specification of the types of assurance activities to be performed, and assurance standards.

Included as part of the acquirer's management planning is how the acquirer intends to track progress, quality, and other project attributes. This requires the specification of the metric information, to be collected and evaluated within the acquirer's organization, which will be supplied by either the acquirer or the providers (such as the developer). The acquirer's configuration management plan and assurance plan is also defined at this time.

If the acquirer intends to formally procure the development of the information system, then the procurement activities and

requirements are defined at this time. If the assurance plan includes procurement of independent verification and validation, then planning and definition of this procurement are also conducted. Results of this entire planning process are documented in the Acquisition Planning section of the Information System Management Plan.

In this phase and all subsequent phases of the life-cycle, lessons learned reports of the management control and status reports are completed and delivered, at a minimum, to the NASA Code Q Software Management and Assurance Program (SMAP). These reports should be completed at periodic intervals, but are provided at least at the end of every life-cycle phase. Each report includes an evaluation of the use of these Information System Life-Cycle and Documentation Standards.

4.2.1.2 Engineering Activities

System feasibility studies are performed and the system concept is developed. The system operational concept including operational scenarios are determined. Results are documented in the Concept section of the Information System Product Specification.

4.2.1.3 Assurance Activities

Assurance activities of this phase include the specification of and actual conduct of reviews of the Acquisition Plan and the Concept. The review specifications and results are documented in the appropriate Quality Assurance sections of the Assurance Specification. Reports describing the outcome of these reviews are documented in the Management Control and Status Reports document.

4.2.1.4 Product Summary

Management Plan: Acquisition Plan
Product Specification: Concept
Assurance Specification: Quality Assurance - Review
Management Control and Status Reports:
- Lessons Learned
- Review Reports
- Status Reports

4.2.1.5 Phase Transition

The Information System Initiation and Concept Phase concludes with the successful completion of the review of the Concept section of the Product Specification and Acquisition Planning section of the Management Plan.

At this and all subsequent phase transition reviews, all products developed or modified within that phase are reviewed and placed under configuration management.

4.2.2 INFORMATION SYSTEM REQUIREMENTS PHASE

The objectives of the Information System Requirements Phase are to formally procure the development and/or independent verification and validation (if required) of the information system, define the development processes, perform requirements analysis, and establish risk and management control mechanisms.

4.2.2.1 Management Activities

If the development of the information system is to be formally procured, then the procurement activities defined in the previous phase are implemented by the acquirer. These include preparation of the statement of work (SOW) and request for proposal (RFP) package, source evaluation and selection, and contract negotiation. If independent verification and validation (IV&V) is to be procured, then these procurements activities are implemented by the acquirer.

After procurement, or at the beginning of this phase if no formal procurements are necessary, the planning for development is conducted by the development provider. This Development Plan conforms to the process requirements and constraints specified in the Acquisition Plan. The Development Plan includes the identification of the approach and definition of the methods for all activities (management, engineering, and assurance) performed by the development provider. At a minimum these include:

- work breakdown structure, resource allocation, and schedules;
- risks and contingencies identification and planning assessment;
- engineering, integration, and operational transition methods and approach, including use of prototyping, phased delivery, and incremental development in the engineering and intergration process;
- configuration management process and procedures to support the engineering approach;
- assurance activities and approach, and quality evaluation approach and metrics;
- detailed requirements for each phase-ending audit and review;
- identification of products to be baselined at or before the end of each phase;

- development personnel training planning; and
- resource, quality, and other tracking information, including specific metric data to be collected during the development process.

If incremental development adaptation is utilized, the definition of the specific increments along with the prioritization approach to be used in selecting which parts of the information system will be developed first is documented within the Development Planning section of the Management Plan.

If new procedures and standards are required, they are developed and documented in the standards repository. (Note that it may be appropriate to generate a development plan and product specification to document the development process of new standards or other support products.)

The approaches and mechanisms defined during this planning process are documented in the Development Plan section of the Information System Management Plan. They are used in subsequent phases for the development, tracking, and control of the information system by the development provider.

If independent verification and validation is specified in the Management Plan, then the approach and methods are defined and documented in the Verification and Validation Planning subsection of the Assurance Plan section of the acquirer's Acquisition Planning section of the Management Plan.

The acquirer, or designated provider, develops the sustaining engineering and operations approach for support of the information system after delivery. This includes planning for maintenance, repair, upgrades, spares, logistics training, and other aspects appropriate to the specific information system. This information is documented in the Sustaining Engineering and Operations Planning section in the Information System Management Plan. If evolutionary acquisition is specified or anticipated, the acquirer or designee prepares the Evolutionary Acquisition Planning section of the Management Plan.

Management participates in the product reviews, and/or evaluates the review and status reports, to determine the readiness to proceed to the next phase. Management is responsible for ensuring that all activities of this phase have been conducted and documented before the design activities of the next phase are initiated.

If discrepancy reports or change proposals are generated in this phase, management is responsible to ensure they are dispositioned and responsibility for resolution assigned.

4.2.2.2 Engineering Activities

The engineering activities of this phase include the definition of the technical requirements with traceability to the design of the next higher level information system in the system decomposition tree (if any). The activities performed to support the requirements definition may include:

a) User needs investigation.

b) User scenarios development. These scenarios detail the user interface requirements to the system but do not detail the specific man-machine interface.

c) Prototyping, as required and defined in the engineering and integration approach in the Development Plan section of the Management Plan.

d) External interface definition and evaluation.

e) Requirements synthesis and analysis.

f) Partitioning of the requirements for phased delivery, if required.

The results are documented in the Requirements section of the Information System Product Specification. In addition, a preliminary version of the User's Guide section of the Information System Product Specification is developed.

If phased deliveries are identified in the information system engineering and integration approach defined in the Development Planning section of the Management Plan, then the partitioning of the requirements into specific deliverables is performed and documented in the Requirements section.

If the development of the information system is being formally procured, the acquirer may develop the requirements as part of the SOW/RFP package.

Metric information (as specified in the Development Planning section of the Management Plan) is collected for the tracking and evaluation of the information system and documented in the Management Control and Status Reports document.

4.2.2.3 Assurance Activities

The acceptance test process is initiated in this phase through the development of the Acceptance Test Specifications, in conformance with the Assurance Plan's approach (detailed in the Management Plan), and supports any phased delivery requirements. Acceptance tests are based on requirements and user scenarios. The acceptance test information is documented in the appropriate testing section(s) of the Assurance Specification.

If verification and validation or independent verification and validation has been specified in the Management Plan, then the validation specifications are defined. The specifications, criteria, procedures, measurement, and expected results for verification activities for (at least) this phase are developed. Verification activities for this phase are conducted and results documented. All (independent) verification and validation assurance information is documented in the appropriate Verification and Validation section of the Assurance Specification. Any verification reports generated are documented in the Management Control and Status Reports document.

The specifications, procedures, criteria, etc. for other quality, safety, and security assurance activities, as specified in the Management Plan to be conducted in this phase, are also generated.

Other assurance activities include reviews of the Management Plan sections developed in this phase, of the Requirements section of the Product Specification, and of sections of the Assurance Specification developed in this phase. If any changes were made to previously reviewed products, these are also reviewed. All review information is documented in the Assurance Specification. The outcome of these reviews is documented in review reports in the Management Control and Status Reports document. All deficiencies and discrepancies are documented in discrepancy reports in the Management Control and Status Reports document and responsibility for resolution assigned.

Metric information (as specified in the Management Plan) is collected for the tracking and evaluation of the information system and documented in performance and/or metric reports in the Management Control and Status Reports document.

4.2.2.4 Product Summary

- Management Plan:
  - Procurement Package
  - Development Plan
  - Sustaining Engineering and Operations Plan
  - Evolutionary Acquisition Plan
  - Independent Verification and Validation Plan
- Product Specification:
  - Requirements Specification
  - User's Guide (preliminary)
- Assurance Specification:
  - Acceptance Test Specifications
  - Quality Assurance Specifications, Procedures, Criteria, and Results
  - Quality Engineering Assurance Specifications, Procedures, Criteria, and Results
  - Safety Assurance Specifications, Procedures, Criteria, and Results
  - Security and Privacy Assurance Specifications, Procedures, Criteria, and Results
  - (Independent) Verification Specifications, Procedures, Criteria, and Results
  - (Independent) Validation Specifications
- Management Control and Status Reports:
  - Lessons Learned
  - Review Reports
  - Status Reports
  - Discrepancy Reports
  - Engineering Change Proposals
  - Performance/Metrics Reports

At any phase, updates may occur to the products of the previous phases.

4.2.2.5 Phase Transition

The Information System Requirements Phase concludes with the successful completion of the Requirements Review for the information system.

4.2.3 INFORMATION SYSTEM DESIGN PHASE

The objective of the Information System Design Phase is to perform architectural design and allocation of the information system requirements to its architectural design elements (either subsystems or components).

4.2.3.1 Management Activities

The collected metric information is evaluated to determine the status of the information system. This information is used for tracking and, when necessary, modifying the resource estimation and other project attributes. Identified risk areas are re-evaluated per the risk assessment process defined in the Information System Management Plan. As a result of the above, planning modifications and updates are made, as required, and documented in the appropriate planning sections of the Management Plan and also in Management and Control Status Reports document.

If the information system design is composed of subsystems, then, as this system enters the subsequent phase (implementation coordination), the lower-level systems each begin a new instance of the information system life-cycle. Incremental development or phased delivery development decisions of this system may impose phased delivery requirements on these information subsystems.

If the information system design is composed of components (hardware, software, and operational procedures) then, as this system enters the subsequent phase (implementation coordination), each component begins execution of its life-cycle. Incremental development or phased delivery development decisions of this information system may impose phased delivery requirements on the components.

If the entire information system is to be acquired off-the-shelf, then procurement and selection preparation is conducted in this phase.

Management participates in the product reviews and/or evaluates the review and status reports to determine the readiness to proceed to the next phase. Management is responsible for ensuring that all activities of this phase have been conducted and documented before the implementation activities of the next phase are initiated.

If discrepancy reports or change proposals are generated in this phase, management is responsible to ensure they are dispositioned and responsibility for resolution assigned.

4.2.3.2 Engineering Activities

Engineering design, requirements allocation, and design partitioning into increments (if required) are conducted in conformance with the methods and approach designated in the engineering and integration approach of the Development Planning section of the Management Plan. Traceability to the requirements is developed and documented.

If the entire information system is intended to be acquired off-the-shelf, then the identification, evaluation, and selection process is initiated in this phase.

During design, the information system's architecture is defined either in terms of subsystems (lower-level information systems) or components (software, hardware, and operational procedures). The interfaces between the design elements (subsystems or components) are defined during this phase. The requirements of this information system are then allocated to the design elements (subsystems or components).

If an incremental development approach is being employed, then the increments are detailed at this time. The increments (partitions of design) defined must be consistent with any phased delivery partitioning defined in the requirements.

Results of all these design activities, along with the design rationale, is documented in the Design section of the Information System Product Specification. (The design rationale and trade-off analysis information is vital to information system maintenance personnel to understand why certain design decisions were made.)

Metric information (as specified in the Management Plan) is collected for the tracking and evaluation of the information system and documented in the Management Control and Status Reports document.

4.2.3.3 Assurance Activities

The acceptance test process continues with the development of the acceptance test procedures and criteria. These are documented in the appropriate Acceptance Test section of the Assurance Specification.

If verification and validation and/or independent verification and validation has been specified in the Management Plan, then verification of the design is conducted and findings documented in the Assurance Specification. Also, validation procedures and criteria are developed. Any reports are documented as Management

Control and Status Reports document verification or review reports.

The integration test process is initiated in the phase through development of the Integration Test Specification. This specification conforms to the assurance approach defined in the Development Plan and supports any incremental development requirements. Integration tests (based on the design information) are documented in the Integration Test section of the Information System Assurance Specification.

Other assurance activities include reviews of all management, engineering, and assurance products developed in this phase plus any changes to previously reviewed products. All review activities are documented in review reports. Deficiencies and discrepancies are documented in discrepancy reports, and responsibility for resolution assigned.

Metric information (as specified in the Management Plan) is collected for the tracking and evaluation of the information system and documented in the Management Control and Status Reports document.

4.2.3.4 Product Summary

Management Plan: Plan Updates
Product Specification: Design Specification
Assurance Specification:
- Acceptance Test Procedures and Criteria
- Integration Test Specifications, Procedures, and Criteria
- Quality Assurance Specifications, Procedures, Criteria, and Results
- Quality Engineering Assurance Specifications, Procedures, Criteria, and Results
- Safety Assurance Specifications, Procedures, Criteria, and Results
- Security and Privacy Assurance Specifications, Procedures, Criteria, and Results
- (Independent) Verification Specifications, Procedures, Criteria, and Results
- (Independent) Validation Procedures and Criteria

Management Control and Status Reports:
- Lessons Learned
- Review Reports
- Status Reports
- Discrepancy Reports
- Engineering Change Proposals
- Performance/Metrics Reports

4.2.3.5 Phase Transition

The Information System Design Phase concludes with the successful completion of the Design Review for the information system. This review is conducted to evaluate the optimization, traceability, correlation, completeness, and the risk of the design, including the corresponding test specifications.

4.2.4 INFORMATION SYSTEM IMPLEMENTATION COORDINATION PHASE

The objective of the Information System Implementation Coordination Phase is to review the products of this information system's design elements (i.e., subsystems or components) and coordinate the interaction among and implementation decisions of them during their development. If the entire system is acquired off-the-shelf, this phase is used to complete procurement of the system and prepare for acceptance testing.

4.2.4.1 Management Activities

The collected metric information is evaluated to determine the status of the information system. This information is used for tracking and, when necessary, modifying the resource estimation and other project attributes. Identified risk areas are re-evaluated per the risk assessment process defined in the Information System Management Plan. As a result of the above, modifications and updates to plans are made, as required, and documented in appropriate Management Plans and Management Control and Status Reports documents.

If the system design was defined in terms of subsystems (lower-level systems) or components during the design phase, then, as their life-cycles are executed, evaluation and coordination is conducted throughout their life-cycles.

If the entire information system is acquired off-the-shelf, then management support of the procurement and selection process is conducted during this phase.

Management participates in the product reviews and/or evaluates the review and status reports to determine the readiness to proceed to the next phase. Management is responsible for ensuring that all activities of this phase have been conducted and documented before the testing activities of the next phase are initiated.

If discrepancy reports or change proposals are generated in this phase, management is responsible to ensure they are dispositioned and responsibility for resolution assigned.

4.2.4.2 Engineering Activities

Implementation activities are conducted in conformance with the methods and approach designated in the Development Plan section of the Management Plan.

If the information system architecture is defined in terms of subsystems (lower-level systems) or components, then review and

coordination of the lower-level technical activities is supported. This includes review and coordination of the interface specifications between the subsystems or components and of their requirements and designs.

If the entire information system is acquired off-the-shelf, then final selection and procurement is conducted in this phase. If the entire information system is acquired as one delivery, then integration testing is not required.

Metric information (as specified in the Management Plan) is collected for the tracking and evaluation of the information system and documented in the Management Control and Status Reports document.

4.2.4.3 Assurance Activities

The remaining preparation for integration test activities, including test procedures, criteria, and test case development, is completed at this time and documented in the Integration Test section of the Information System Assurance Specification. Incremental development requirements must be supported.

Final preparation for acceptance testing is completed at this time, including test case development. Phased delivery requirements must be supported.

In addition to the review of the integration and acceptance test products developed in this phase, assurance activities include the review of all the (next lower-level) subsystems or components products if this system has been so defined. All review activities are documented in review reports and, if necessary, discrepancy reports.

If verification and validation and/or independent verification and validation of this information system is specified in the Management Plan for subsystems or components, then some amount of verification of the (lower-level) subsystems or components products may be conducted and findings documented in the Assurance Specification. In addition, preparation for conducting validation of this information system is completed by the end of this phase.

Metric information (as specified in the Management Plan) is collected for the tracking and evaluation of the information system and documented in the Management Control and Status Reports document.

4.2.4.4 Product Summary

Management Plan: Plan Updates
Product Specification: Updates, as required
Assurance Specification:
- Integration Test Procedures, Criteria, and Cases
- Acceptance Test Cases
- Quality Assurance Specifications, Procedures, Criteria, and Results
- Quality Engineering Assurance Specifications, Procedures, Criteria, and Results
- Safety Assurance Specifications, Procedures, Criteria, and Results
- Security and Privacy Assurance Specifications, Procedures, Criteria, and Results
- (Independent) Verification Specifications, Procedures, Criteria, and Results
- (Independent) Validation Test Cases and Expected Results

Management Control and Status Reports:
- Lessons Learned
- Review Reports
- Status Reports
- Discrepancy Reports
- Engineering Change Proposals
- Performance/Metrics Reports

4.2.4.5 Phase Transition

The Information System Implementation Coordination Phase concludes as (lower-level) subsystems or components become ready for systems integration and test (i.e., complete their Acceptance and Delivery Phase). There is usually no formal transition review. If the entire information system is acquired off-the-shelf, then the phase concludes once that system has been procured.

4.2.5 INFORMATION SYSTEM INTEGRATION AND TEST PHASE

The objective of the Information System Integration and Test is to integrate the (next lower-level) subsystems or components and to perform integration testing.

4.2.5.1 Management Activities

The collected metric information is evaluated to determine the status of the information system. This information is used for tracking and, when necessary, modifying the resource estimation and other project attributes. Identified risk areas are re-evaluated per the risk assessment process defined in the Information System Management Plan. As a result of the above, modifications and updates to plans are made, as required, and documented in appropriate Management Plans and Management Control and Status Reports document.

Management participates in the product reviews, and/or evaluates the review and status reports, to determine the readiness to proceed to the next phase. Management is responsible for ensuring that all activities of this phase have been conducted and documented before the acceptance test activities of the next phase are initiated.

If discrepancy reports or change proposals are generated in this phase, management is responsible to ensure they are dispositioned and responsibility for resolution assigned.

4.2.5.2 Engineering Activities

Integration activities are conducted in conformance with the methods and approach designated in the Development Plan section of the Management Plan. The (next lower-level) subsystems or components which have passed their acceptance testing are integrated.

Integration can be performed incrementally if specified in the Engineering and Integration section of the Development Plan and supported by the definition of the increments in the design document. Each increment undergoes integration testing assurance activities prior to integration with subsequent increments. Component (or subsystem) providers may be required to support system integration.

If the entire information system was acquired off-the-shelf as one delivery, then integration may not be required.

At the completion of integration, the Version Description Document section of the Product Specification is prepared.

Final versions of the user's guide and training materials for users and operators are developed during this phase along with the information system maintenance manual and documented in the appropriate sections of the Information System Product Specification.

Metric information (as specified in the Management Plan) is collected for the tracking and evaluation of the information system and documented in the Management Control and Status Reports document.

4.2.5.3 Assurance Activities

At the completion of integration (for each increment if incremental development is used), integration testing is conducted. Integration testing is often conducted by the engineering development team but may be performed by whatever organization is assigned responsibility per the Development Planning Section of the Management Plan. The results of all integration testing are documented in the appropriate test results section of the Assurance Specification. Any reports are documented in the Management Control and Status Reports document.

At the completion of integration testing, the tests and their results are reviewed for assurance that the information system is ready for acceptance testing. The review results are documented in the Assurance Specification. Deficiencies and discrepancies are documented in discrepancy reports in the Management Control and Status Reports document and responsibility for resolution assigned.

If verification and validation and/or independent verification and validation has been specified in the Management Plan, then verification of the product against the Design sections of the Product Specification is conducted and findings documented in the appropriate section of the Assurance Specification. If preparation for validation was not complete, it is finished and documented in the appropriate section of the Assurance Specification. Any reports are documented in the Management Control and Status Reports document.

Metric information (as specified in the Management Plan) is collected for the tracking and evaluation of the information system and documented in the Management Control and Status Reports document.

4.2.5.4 Product Summary

Management Plan: Plan Updates
Product Specification:
- Information System (post-integration test)
- Version Description Document
- User's Guide
- Training Materials
- Maintenance Manual

Assurance Specification:
- Integration Test Results
- Quality Assurance Specifications, Procedures, Criteria, and Results
- Quality Engineering Assurance Specifications, Procedures, Criteria, and Results
- Safety Assurance Specifications, Procedures, Criteria, and Results
- Security and Privacy Assurance Specifications, Procedures, Criteria, and Results
- (Independent) Verification Specifications, Procedures, Criteria, and Results

Management Control and Status Reports:
- Lessons Learned
- Review Reports
- Status Reports
- Discrepancy Reports
- Engineering Change Proposals
- Performance/Metrics Reports

4.2.5.5 Phase Transition

The Information System Integration and Test Phase concludes with the successful completion of the Test Readiness Review (TRR) of the information system. The Test Readiness Review is conducted to determine whether system acceptance test preparation is complete and to assure that the information system is ready for formal acceptance testing. A successful Test Readiness Review is usually predicated on the acquirer's determination that the acceptance test procedures and previous testing results form a satisfactory basis for proceeding into the Acceptance Testing Phase.

4.2.6 INFORMATION SYSTEM ACCEPTANCE AND DELIVERY PHASE

The objectives of the Information System Acceptance and Delivery Phase are to validate that the information system meets its documented requirements and the users' needs and to prepare the information system for delivery.

4.2.6.1 Management Activities

The collected metric information is evaluated to determine the status of the information system. This information is used for tracking and, when necessary, modifying the resource estimation and other project attributes. Identified risk areas are re-evaluated per the risk assessment process defined in the Information System Management Plan. As a result of the above, modifications and updates to plans are made, as required, and documented in appropriate Management Plans and Management Control and Status Reports document.

Management participates in the product reviews, and/or evaluates the review and status reports, to determine the readiness to proceed to the next phase. Management is responsible for ensuring that all activities of this phase have been conducted and documented before final delivery of the information system and initiation of the sustaining engineering activities.

The final accept or reject decision of the information system is the responsibility of management.

If discrepancy reports or change proposals are generated in this phase, management is responsible to ensure they are dispositioned and responsibility for resolution assigned.

4.2.6.2 Engineering Activities

The engineering activities include preparation of the information system for delivery and performing operational transition activities, such as training and generation of a version-compatible release of the User's Guide and Version Description sections of the Product Specification.

Metric information (as specified in the Development Plan) is collected for the tracking and evaluation of the information system and documented in the Management Control and Status Reports document.

4.2.6.3 Assurance Activities

Acceptance test activities are conducted in conformance with the methods and approach designated in the Assurance Plan section of the Management Plan. The activities in this phase include formal testing of the information system against the requirements and the user scenarios.

If phased delivery is specified, then the acceptance testing is conducted on the system defined for the current delivery against the requirements defined for that delivery. The results from acceptance testing are documented in the Assurance Specification.

If verification and validation and/or independent verification and validation is specified in the Management Plan, then the appropriate verification activities and all validation testing are conducted. Results are documented in the appropriate sections of the Assurance Specification. Reports are documented in the Management Control and Status Reports document.

Acceptance test results and reports, along with any (independent) validation results and reports, are analyzed. An acceptance review is conducted and documented in a review report. Deficiencies and discrepancies are documented in discrepancy reports in the Management Control and Status Reports document, and responsibility for resolution is assigned.

Metric information (as specified in the Management Plan) is collected for the tracking and evaluation of the information system and documented in the Management Control and Status Reports document.

4.2.6.4 Product Summary

Management Plan: Plan Updates
Product Specification:
- Information System (post-acceptance test)
- Version Description (update)
- User's Guide and Training Materials (update)

Assurance Specification:
- Acceptance Test Results
- Quality Assurance Specifications, Procedures, Criteria, and Results
- Quality Engineering Assurance Specifications, Procedures, Criteria, and Results
- Safety Assurance Specifications, Procedures, Criteria, and Results
- Security and Privacy Assurance Specifications, Procedures, Criteria, and Results
- (Independent) Verification and Validation Results

Management Control and Status Reports:
- **Lessons Learned**
- **Review Reports**
- **Status Reports**
- **Discrepancy Reports**
- **Engineering Change Proposals**
- **Performance/Metrics Reports**

4.2.6.5 Phase Transition

The Information System Acceptance and Delivery Phase concludes with the successful completion of the Functional Configuration Audit (FCA) and the Physical Configuration Audit (PCA), resulting in an accept or reject decision. The object of the Functional Configuration Audit and the Physical Configuration Audit is to validate that the actual performance of the information system as determined through test complies with the requirements specifications, and to identify the test report(s) and data which document results of acceptance tests.

4.2.7 INFORMATION SYSTEM SUSTAINING ENGINEERING AND OPERATIONS PHASE

The objectives of the Information System Sustaining Engineering and Operations Phase are to sustain the operational capabilities of the information system, to make "repairs" and upgrades within the context of the original concept of the system, and to conduct user and operations training and support.

Upgrades, either outside the scope of the original concept or involving the major rework of the implementation, may be considered outside of the scope of sustaining engineering activities and, thus, should be addressed in the evolutionary acquisition of the information system. Sustaining engineering, as defined here, includes maintenance.

4.2.7.1 Management Activities

Review and approval of discrepancy reports and change proposals is conducted by management. Modifications and updates to plans are made and documented in appropriate Management Plans and Management Control and Status Reports documents. Plans for change incorporation must adhere to the same acquisition and assurance requirements as originally identified for the information system classification level.

Management participates in the product reviews, and/or evaluates the review and status reports, to determine the readiness to deliver the next release of the information system. Management is responsible for ensuring that all activities of this phase are conducted and documented.

If discrepancy reports or change proposals are generated in this phase, management is responsible to ensure they are dispositioned and responsibility for resolution assigned.

4.2.7.2 Engineering Activities

Technical evaluation of discrepancy reports and change proposals is performed. Changes to the information system are only implemented based on approved change requests. This requires iteration through the requirements, design, implementation, and testing phases of the life-cycle. The activities defined in those phases are performed, resulting in updates to the specified products.

In addition to supporting the operations of the information system, user and operator training may be required as an on-going services.

Metric information (as specified in the Management Plan) is collected for the tracking and evaluation of the information system and documented in the Management Control and Status Reports document.

4.2.7.3 Assurance Activities

To maintain the integrity and quality of the information system, the same types and levels of assurance must be conducted during sustaining engineering as were performed during development (previous phases of the life-cycle). Reviews of all updated products are conducted and documented in review reports. Acceptance testing, verification and validation, and independent verification and validation activities are performed, as specified in the Management Plan. Regression testing is performed to assure that operational integrity is maintained. Test results are documented in the Assurance Specification.

If required by system changes, modification to assurance specifications, criteria, test cases, and expected results are made. This will require updates to the Assurance Specification.

Metric information (as specified in the Management Plan) is collected for the tracking and evaluation of the information system and documented in the Management Control and Status Reports document.

4.2.7.4 Product Summary

Management Plan: Updates
Product Specification: Updates
Assurance Specification: Updates
Management Control and Status Reports:
- Discrepancy Reports
- Engineering Change Proposals
- Status Reports
- Review Reports
- Performance/Metrics Reports

4.2.7.5 Phase Transition

The Information System Sustaining Engineering and Operations Phase concludes with the retirement of the system or the transition to its next evolutionary phase. Reviews conducted during the Sustaining Engineering and Operations Phase are dependent upon the types of changes required. Sustaining Engineering requires re-visiting life-cycle phases. For each life-cycle phase revisited, the appropriate phase transition reviews are conducted.

4.3 Software Life-Cycle Definition

The software life-cycle consists of the following phases:

- Software Concept and Initiation
- Software Requirements
- Software Design
  - Architectural Design
  - Detailed Design
- Software Implementation
- Software Integration and Test
- Software Acceptance and Delivery
- Software Sustaining Engineering and Operations (Support)

This life-cycle is instantiated for each software component (and software subcomponents) in the decomposition tree.

4.3.1 SOFTWARE CONCEPT AND INITIATION PHASE

The objectives of the Software Concept and Initiation Phase are to evaluate the feasibility of the proposed software concept (if not addressed during the feasibility evaluation of the information system), define the software concept, and develop the management, engineering, and assurance strategies and constraints.

Some of the activities for this phase may not be required due to their previous execution at higher levels in the system decomposition. For example, the software concept may have been fully defined at the information system level and the management planning may simply reference sections in the information system management plan.

4.3.1.1 Management Activities

Management planning begins in this phase by defining both the activities and structure of the organization obtaining the software (called the acquirer), and the development and assurance process requirements. Development process requirements definition includes procurement strategy decisions, life-cycle requirements and constraints, engineering standards and constraints, delivery requirements, and tracking and control mechanisms. Assurance process requirements definition includes criticality classification of the software, specification of the types of assurance activities to be performed, and assurance standards.

Included as part of the acquirer's management planning is how the acquirer intends to track progress, quality, and other project attributes. This requires the specification of the metric

information, to be collected and evaluated within the acquirer's organization, which will be supplied by either the acquirer or the providers (such as the developer). The acquirer's configuration management plan and assurance plan is also defined at this time.

If the acquirer intends to formally procure the development of the software, then the procurement activities and requirements are defined at this time. If the assurance plan includes procurement of independent verification and validation, then planning and definition of this procurement are also conducted. Results of this entire planning process are documented in the Acquisition Planning section of the Software Management Plan.

In this phase and all subsequent phases of the life-cycle, lessons learned reports of the management control and status reports are completed and delivered, at a minimum, to the NASA Code Q Software Management and Assurance Program (SMAP). These reports should be completed at periodic intervals, but are provided at least at the end of every life-cycle phase. Each report includes an evaluation of the use of the software aspects of these Information System Life-Cycle and Documentation Standards.

4.3.1.2 Engineering Activities

Software feasibility studies are performed and the software concept is developed. The software operational concept including operational scenarios are determined during this phase. Results are documented in the Concept section of the Software Product Specification.

4.3.1.3 Assurance Activities

Assurance activities of this phase include the specification of and actual conduct of reviews of the Acquisition Plan and the Concept. The review specifications and results are documented in the appropriate Quality Assurance sections of the Assurance Specification. Reports describing the outcome of these reviews are documented in the Management Control and Status Reports document.

4.3.1.4 Product Summary

Management Plan: Acquisition Plan
Product Specification: Concept
Assurance Specification: Quality Assurance - Review
Management Control and Status Reports:
- Lessons Learned
- Review Reports
- Status Reports

4.3.1.5 Phase Transition

The Software Initiation and Concept Phase concludes with the successful completion of the review of the Concept section of the Product Specification and Acquisition Planning section of the Management Plan.

At this and all subsequent phase transition reviews, all products developed or modified within that phase are reviewed and placed under configuration management.

4.3.2 SOFTWARE REQUIREMENTS PHASE

The objectives of the Software Requirements Phase are to formally procure the development and/or independent verification and validation (if required) of the software, define the development process, perform requirements analysis, and establish risk and management control mechanisms.

4.3.2.1 Management Activities

If the development of the software is to be formally procured, then the procurement activities defined in the previous phase are implemented by the acquirer. These include preparation of the statement of work (SOW) and request for proposal (RFP) package, source evaluation and selection, and contract negotiation. If independent verification and validation (IV&V) is to be procured, then these procurements activities are implemented by the acquirer.

After procurement, or at the beginning of this phase if no formal procurements are necessary, the planning for development is conducted by the development provider. This Development Plan conforms to the process requirements and constraints specified in the Acquisition Plan. The Development Plan includes the identification of the approach and definition of the methods for all activities (management, engineering, and assurance) performed by the development provider. At a minimum these include:

- work breakdown structure, resource allocation, and schedules;
- risks and contingencies identification and planning assessment;
- engineering, integration, and operational transition methods and approach, including use of prototyping, phased delivery, and incremental development in the engineering and intergration process;
- configuration management process and procedures to support the engineering approach;
- assurance activities and approach, and quality evaluation approach and metrics;
- detailed requirements for each phase-ending audit and review;
- identification of products to be baselined at or before the end of each phase;

- development personnel training planning; and
- resource, quality, and other tracking information, including specific metric data to be collected during the development process.

If incremental development adaptation is utilized, the definition of the specific increments along with the prioritization approach to be used in selecting which parts of the software will be developed first is documented within the Development Planning section of the Management Plan.

If new procedures and standards are required, they are developed and documented in the standards repository. (Note that it may be appropriate to generate a development plan and product specification to document the development process of new standards or other support products.)

The approaches and mechanisms defined during this planning process are documented in the Development Plan section of the Software Management Plan. They are used in subsequent phases for the development, tracking, and control of the software by the development provider.

If independent verification and validation is specified in the Management Plan, then the approach and methods are defined and documented in the Verification and Validation Planning subsection of the Assurance Plan section of the acquirer's Acquisition Planning section of the Management Plan.

The acquirer, or designated provider, develops the sustaining engineering and operations approach for support of the software after delivery. This includes planning for maintenance, upgrades, training, and other aspects appropriate to the software. Sustaining Engineering may be specified for software, or it may be specified as an information system activity supported, as necessary, by software. This information is documented in the Sustaining Engineering and Operations Planning section in the Software Management Plan.

Evolutionary acquisition is usually specified only at the information system level. If evolutionary acquisition is specified or anticipated for the software, the acquirer or designee prepares the Evolutionary Acquisition Planning section of the Management Plan.

Management participates in the product reviews, and/or evaluates the review and status reports, to determine the readiness to proceed to the next phase. Management is responsible for ensuring that all activities of this phase have been conducted and documented before the design activities of the next phase are initiated.

If discrepancy reports or change proposals are generated in this phase, management is responsible to ensure they are dispositioned and responsibility for resolution assigned.

4.3.2.2 Engineering Activities

The engineering activities of this phase include the definition of the technical requirements with traceability to the design of the next higher level design in the system decomposition tree, either information system or software component. The activities performed to support the requirements definition may include:

a) User needs investigation.

b) User scenarios development. These scenarios detail the user interface requirements to the software but do not detail the specific man-machine interface.

c) Prototyping, as required and defined in the engineering and integration approach in the Development Plan section of the Management Plan.

d) External interface definition and evaluation.

e) Requirements synthesis and analysis.

f) Partitioning of the requirements for phased delivery, if required.

The results are documented in the Requirements section of the Software Product Specification. In addition, a preliminary version of the User's Guide section of the Software Product Specification is developed.

If phased deliveries are identified in the software engineering and integration approach defined in the Development Planning section of the Management Plan, then the partitioning of the requirements into specific deliverables is performed and documented in the Requirements section.

If the development of the software is being formally procured, the acquirer may develop the requirements as part of the SOW/RFP package.

Metric information (as specified in the Development Planning section of the Management Plan) is collected for the tracking and evaluation of the software and documented in the Management Control and Status Reports document.

4.3.2.3 Assurance Activities

The acceptance test process is initiated in this phase through the development of the Acceptance Test Specifications, in conformance with the Assurance Plan's approach (detailed in the Management Plan), and supports any phased delivery requirements. Acceptance tests are based on requirements and user scenarios. The acceptance test information is documented in the appropriate testing section(s) of the Assurance Specification.

If verification and validation or independent verification and validation has been specified in the Management Plan, then the validation specifications are defined. The specifications, criteria, procedures, measurement, and expected results for verification activities for (at least) this phase are developed. Verification activities for this phase are conducted and results documented. All (independent) verification and validation assurance information is documented in the appropriate Verification and Validation section of the Assurance Specification. Any verification reports generated are documented in the Management Control and Status Reports document.

The specifications, procedures, criteria, etc. for other quality, safety, and security assurance activities, as specified in the Management Plan to be conducted in this phase, are also generated.

Other assurance activities include reviews of the Management Plan sections developed in this phase, of the Requirements section of the Product Specification, and of sections of the Assurance Specification developed in this phase. If any changes were made to previously reviewed products, these are also reviewed. All review information is documented in the Assurance Specification. The outcome of these reviews is documented in review reports in the Management Control and Status Reports document. All deficiencies and discrepancies are documented in discrepancy reports in the Management Control and Status Reports document and responsibility for resolution assigned.

Metric information (as specified in the Management Plan) is collected for the tracking and evaluation of the software and documented in performance and/or metric reports in the Management Control and Status Reports document.

4.3.2.4 Product Summary

Management Plan:
- Procurement Package
- Development Plan
- Sustaining Engineering and Operations Plan
- Evolutionary Acquisition Plan
- Independent Verification and Validation Plan

Product Specification:
- Requirements Specification
- User's Guide (preliminary)

Assurance Specification:
- Acceptance Test Specifications
- Quality Assurance Specifications, Procedures, Criteria, and Results
- Quality Engineering Assurance Specifications, Procedures, Criteria, and Results
- Safety Assurance Specifications, Procedures, Criteria, and Results
- Security and Privacy Assurance Specifications, Procedures, Criteria, and Results
- (Independent) Verification Specifications, Procedures, Criteria, and Results
- (Independent) Validation Specifications

Management Control and Status Reports:
- Lessons Learned
- Review Reports
- Status Reports
- Discrepancy Reports
- Engineering Change Proposals
- Performance/Metrics Reports

At any phase, updates may occur to the products of the previous phases.

4.3.2.5 Phase Transition

The Software Requirements Phase concludes with the successful completion of the Requirements Review for the software.

4.3.3 SOFTWARE DESIGN PHASE

The Software Design Phase may be partitioned into two parts, with a phase transition review at the conclusion of each part if this software component is not further partitioned into software subcomponents. The two parts are architectural design and detailed design.

4.3.3.1 SOFTWARE ARCHITECTURAL DESIGN

The objective of the Software Architectural Design Phase is to perform architectural design and allocation of the software component's requirements to its architectural design elements or software subcomponents.

4.3.3.1.1 Management Activities

The collected metric information is evaluated to determine the status of the software. This information is used for tracking and, when necessary, modifying the resource estimation and other project attributes. Identified risk areas are re-evaluated per the risk assessment process defined in the Software Management Plan. As a result of the above, planning modifications and updates are made, as required, and documented in the appropriate planning sections of the Management Plan and also in the Management and Control Status Reports document. In addition, any reuse or commonality, and buy, build, or modify, plans for the software should be detailed at this time.

If the software design is composed of software subcomponents, then the lower level software components each begin a new instance of the software life-cycle and this software component enters an implementation coordination phase analogous to the information system phase of this name. Incremental development or phased delivery development decisions of this software may impose phased delivery requirements on these software subcomponents.

If the software is not further decomposed into software subcomponents, then the architectural design into design elements is conducted. This software component then proceeds to the detailed design phase.

If the entire software component is to be acquired off-the-shelf, then procurement and selection preparation is conducted in this phase.

Management participates in the product reviews and/or evaluates the review and status reports to determine the readiness to proceed to the next phase. Management is responsible for

ensuring that all activities of this phase have been conducted and documented before the implementation activities of the next phase are initiated.

If discrepancy reports or change proposals are generated in this phase, management is responsible to ensure they are dispositioned and responsibility for resolution assigned.

4.3.3.1.2 Engineering Activities

Engineering design, requirements allocation, and design partitioning into increments (if required) are conducted in conformance with the methods and approach designated in the engineering and integration approach of the Development Planning section of the Management Plan. Traceability to the requirements is developed and documented.

If the entire software component is intended to be acquired off-the-shelf, then the identification, evaluation, and selection process is initiated in this phase.

During design, the software's architecture is defined either in terms of software subcomponents (lower-level software components) or design elements. The interfaces between the design elements or subcomponents are defined during this phase. The requirements of this software are then allocated to the design elements or subcomponents.

If an incremental development approach is being employed, then the increments are detailed at this time. The increments (partitions of design) defined must be consistent with any phased delivery partitioning defined in the requirements.

Results of all these design activities, along with the design rationale, is documented in the Architectural Design section of the Software Product Specification. (The design rationale and trade-off analysis information is vital to software maintenance personnel to understand why certain design decisions were made.)

Metric information (as specified in the Management Plan) is collected for the tracking and evaluation of the software and documented in the Management Control and Status Reports document.

4.3.3.1.3 Assurance Activities

The acceptance test process continues with the development of the acceptance test procedures and criteria. These are documented in the appropriate Acceptance Test section of the Software Assurance Specification.

If verification and validation and/or independent verification and validation has been specified in the Management Plan, then verification of the architectural design is conducted and findings documented in the Assurance Specification. Also, validation procedures and criteria are developed. Any verification or review reports are documented in the Management Control and Status Reports document.

The integration test process is initiated in the phase through development of the Integration Test Specification. This specification conforms to the assurance approach defined in the Development Plan and supports any incremental development requirements. Integration tests (based on the design information) are documented in the Integration Test section of the Software Assurance Specification.

Other assurance activities include reviews of all management, engineering, and assurance products developed in this phase plus any changes to previously reviewed products. All review activities are documented in review reports. Deficiencies and discrepancies are documented in discrepancy reports, and responsibility for resolution assigned.

Metric information (as specified in the Management Plan) is collected for the tracking and evaluation of the software and documented in the Management Control and Status Reports document.

4.3.3.1.4 Product Summary

Management Plan: Plan Updates
Product Specification: Design Specification -- Architectural
Assurance Specification:
- Acceptance Test Procedures and Criteria
- Integration Test Specifications, Procedures, and Criteria
- Quality Assurance Specifications, Procedures, Criteria, and Results
- Quality Engineering Assurance Specifications, Procedures, Criteria, and Results
- Safety Assurance Specifications, Procedures, Criteria, and Results
- Security and Privacy Assurance Specifications, Procedures, Criteria, and Results

(Independent) Verification Specifications, Procedures, Criteria, and Results
(Independent) Validation Procedures and Criteria
Management Control and Status Reports:
Lessons Learned
Review Reports
Status Reports
Discrepancy Reports
Engineering Change Proposals
Performance/Metrics Reports

4.3.3.1.5 Phase Transition

The Software Architectural Design Phase concludes with the successful completion of the Architectural (or Preliminary) Design Review for the software. This review is conducted to evaluate the optimization, traceability, correlation, completeness, and the risk of the design, including the corresponding test specifications.

4.3.3.2 SOFTWARE DETAILED DESIGN PHASE

The objectives of the Software Detailed Design Phase are to complete design to the unit level and prepare for software implementation. The activities in this phase are conducted only for the lowest software components in the decomposition tree and are dependent upon buy, build, or modify decisions.

4.3.3.2.1 Management Activities

The collected metric information is evaluated to determine the status of the software. This information is used for tracking and, when necessary, modifying the resource estimation and other project attributes. Identified risk areas are re-evaluated per the risk assessment process defined in the Software Management Plan. As a result of the above, planning modifications and updates are made, as required, and documented in the appropriate planning sections of the Management Plan and also in the Management and Control Status Reports document.

If the entire software component is to be acquired off-the-shelf, then procurement and selection preparation is conducted in this phase.

Management participates in the product reviews and/or evaluates the review and status reports to determine the readiness to proceed to the next phase. Management is responsible for ensuring that all activities of this phase have been conducted and documented before the implementation activities of the next phase are initiated.

If discrepancy reports or change proposals are generated in this phase, management is responsible to ensure they are dispositioned and responsibility for resolution assigned.

4.3.3.2.2 Engineering Activities

Detailed design activities are conducted in conformance with the methods and approach designated in the Development Plan section of the Software Management Plan.

Software detailed design includes design of the software design elements and software units. Buy, build, or modify decisions are made in this phase, and any necessary procurement activities conducted. The results of all detailed design activities are documented in the Detailed Design section of the Software Product Specification.

If verification and validation and/or independent verification and validation has been specified in the Management Plan, then

verification of the detailed design is conducted and findings documented in the Assurance Specification. Any reports are documented as Management Control and Status Reports document verification or review reports.

If the entire software component is acquired off-the-shelf as a single package, then detailed design activities, unit test development, and integration testing may be omitted. (The implementation phase would consist of final procurement activities and preparation for acceptance testing.)

Metric information (as specified in the Development Plan) is collected for the tracking and evaluation of the software component and documented in the Management Control and Status Reports document.

4.3.3.2.3 Assurance Activities

If the software component is acquired off-the-shelf as a single package, then the software acceptance test cases are prepared in this phase.

If the software is being developed, then software unit test specifications, procedures, and criteria are generated in this phase and documented in the Unit Test section of the Assurance Specification.

Other assurance activities include reviews of all management, engineering, and assurance products developed in this phase plus any changes to previously reviewed products. All review activities are documented in review reports. Deficiencies and discrepancies are documented in discrepancy reports in the Management Control and Status Reports document and responsibility for resolution assigned.

Metric information (as specified in the Management Plan) is collected for the tracking and evaluation of the software and documented in the Management Control and Status Reports document.

4.3.3.2.4 Product Summary

Management Plan: Plan Updates
Product Specification: Design Specification -- Detailed
Assurance Specification:
- Acceptance Test Cases
- Unit Test Specifications, Procedures, and Criteria
- Quality Assurance Specifications, Procedures, Criteria, and Results

Quality Engineering Assurance Specifications, Procedures, Criteria, and Results
Safety Assurance Specifications, Procedures, Criteria, and Results
Security and Privacy Assurance Specifications, Procedures, Criteria, and Results
Management Control and Status Reports:
Lessons Learned
Review Reports
Status Reports
Discrepancy Reports
Engineering Change Proposals
Performance/Metrics Reports

4.3.3.2.5 Phase Transition

The Software Detailed Design Phase concludes with the successful completion of the Software Critical Design Review (CDR). The Critical Design Review includes a formal technical review of the detailed design, including databases and interfaces. The Critical Design Review is normally accomplished for the purpose of establishing integrity of software design at the unit level prior to coding and testing. If incremental development (or phased delivery) is being employed in the development process, the Critical Design Review will be of the appropriate increment under development.

4.3.4 SOFTWARE IMPLEMENTATION PHASE

The objectives of the Software Implementation Phase are to code and to unit test the software component.

If the software component has been designed in terms of lower level software subcomponents, then the activities in this phase are analogous to those of the Information System Implementation Coordination Phase described in Section 4.2.4.

If the entire software component is acquired off-the-shelf, this phase is used to finish procuring the software and to prepare for acceptance testing.

4.3.4.1 Management Activities

The collected metric information is evaluated to determine the status of the software. This information is used for tracking and, when necessary, modifying the resource estimation and other project attributes. Identified risk areas are re-evaluated per the risk assessment process defined in the Software Management Plan. As a result of the above, modifications and updates to plans are made, as required, and documented in appropriate Management Plans and Management Control and Status Reports document.

If the software design was defined in terms of software subcomponents during the architectural design phase, then, as their life-cycles are executed, evaluation and coordination is conducted.

If the entire software component is acquired off-the-shelf, then management support of the procurement and selection process is conducted during this phase.

Management participates in the product reviews and/or evaluates the review and status reports to determine the readiness to proceed to the next phase. Management is responsible for ensuring that all activities of this phase have been conducted and documented before the testing activities of the next phase are initiated.

If discrepancy reports or change proposals are generated in this phase, management is responsible to ensure they are dispositioned and responsibility for resolution assigned.

4.3.4.2 Engineering Activities

Implementation activities are conducted in conformance with the methods and approach designated in the Development Plan section of the Management Plan.

If the software has been designed in terms of design elements and detailed design conducted to the unit level, then the engineering activities for this phase include code development for the software units. Code is documented in the Software Product Specification.

If the software design is defined in terms of software subcomponents, then review and coordination of the lower-level technical activities is supported. This includes review and coordination of the interface specifications between the subcomponents, and review of their requirements and designs for compatibility.

If the entire software component is acquired off-the-shelf, then final selection and procurement is conducted in this phase. If the entire software is acquired as one delivery, then unit and integration testing is not required.

Metric information (as specified in the Management Plan) is collected for the tracking and evaluation of the software and documented in the Management Control and Status Reports document.

4.3.4.3 Assurance Activities

Unit test specifications, procedures, criteria, test cases, etc., are developed, the tests conducted, and results recorded according to the plans specified in the Assurance Planning sections of the Development Plan. All unit test information is recorded in the Unit Test section of the Assurance Specification. Test reports are documented in the Management Control and Status Reports document.

The remaining preparation for integration test activities, including test case development, is completed at this time and documented in the Integration Test section of the Software Assurance Specification. Incremental development requirements must be supported.

Final preparation for acceptance testing is completed at this time, including test case development. Phased delivery requirements must be supported.

In addition to the review of the integration and acceptance test products developed in this phase, assurance activities may

include code walkthroughs, inspections, and audits. If this software has been defined in terms of software subcomponents, then assurance activities include the review of all the (next lower-level) subcomponents products. All review activities are documented in review reports and, if necessary, discrepancy reports in the Management Control and Status Reports document and responsibility for resolution assigned.

If verification and validation and/or independent verification and validation has been specified in the Management Plan, then verification of the code is conducted and findings documented in the Assurance Specification. Any reports are documented as Management Control and Status Reports document verification or review reports.

If verification and validation and/or independent verification and validation of this software is specified in the Management Plan for subcomponents, then some amount of verification of the (lower-level) subcomponents products may be conducted and findings documented in the Assurance Specification. In addition, preparation for conducting validation of this software is completed by the end of this phase.

Metric information (as specified in the Management Plan) is collected for the tracking and evaluation of the software and documented in the Management Control and Status Reports document.

4.3.4.4 Product Summary

Management Plan: Plan Updates
Product Specification: Software Component (pre-test)
Assurance Specification:
- Unit Tests
- Integration Test Cases
- Acceptance Test Cases
- Quality Assurance Specifications, Procedures, Criteria, and Results
- Quality Engineering Assurance Specifications, Procedures, Criteria, and Results
- Safety Assurance Specifications, Procedures, Criteria, and Results
- Security and Privacy Assurance Specifications, Procedures, Criteria, and Results
- (Independent) Verification Specifications, Procedures, Criteria, and Results
- (Independent) Validation Test Cases and Expected Results

Management Control and Status Reports:
- Lessons Learned
- Review Reports
- Status Reports
- Discrepancy Reports
- Engineering Change Proposals
- Performance/Metrics Reports

4.3.4.5 Phase Transition

The Software Implementation Phase concludes with the completion of unit testing and peer reviews (walkthroughs, etc.) of the software units.

If the software is defined in terms of subcomponents and this phase is an implementation coordination activity, then this phase concludes as subcomponents become ready for software integration and test (i.e., complete their Acceptance and Delivery Phase). If the entire software is acquired off-the-shelf, then the phase concludes once the software has been procured.

4.3.5 SOFTWARE INTEGRATION AND TEST PHASE

The objectives of the Software Integration and Test Phase are to integrate the software units (or, if applicable, the software subcomponents) and to perform integration testing.

4.3.5.1 Management Activities

The collected metric information is evaluated to determine the status of the software. This information is used for tracking and, when necessary, modifying the resource estimation and other project attributes. Identified risk areas are re-evaluated per the risk assessment process defined in the Software Management Plan. As a result of the above, modifications and updates to plans are made, as required, and documented in appropriate Management Plans and Management Control and Status Reports document.

Management participates in the product reviews and/or evaluates the review and status reports to determine the readiness to proceed to the next phase. Management is responsible for ensuring that all activities of this phase have been conducted and documented before the testing activities of the next phase are initiated.

If discrepancy reports or change proposals are generated in this phase, management is responsible to ensure they are dispositioned and responsibility for resolution assigned.

4.3.5.2 Engineering Activities

Integration activities are conducted in conformance with the methods and approach designated in the Development Plan section of the Management Plan. The software units or (next lower-level) subcomponents which have passed their acceptance testing are integrated.

Integration can be performed incrementally if specified in the Engineering and Integration section of the Development Plan and supported by the definition of the increments in the design document. Each increment undergoes integration testing assurance activities prior to integration with subsequent increments. If applicable, subcomponent providers may be required to support software integration.

If the entire software component was acquired off-the-shelf as one delivery, then integration may not be required.

At the completion of integration, the Version Description Document section of the Product Specification is prepared.

Final versions of the user's guide and training materials are developed during this phase along with the software maintenance manual and documented in the appropriate sections of the Software Product Specification.

Metric information (as specified in the Management Plan) is collected for the tracking and evaluation of the software and documented in the Management Control and Status Reports document.

4.3.5.3 Assurance Activities

At the completion of integration (for each increment if incremental development is used), integration testing is conducted. Integration testing is often conducted by the engineering development team but may be performed by whatever organization is assigned responsibility per the Development Planning Section of the Management Plan. The results of all integration testing are documented in the appropriate test results section of the Assurance Specification. Any reports are documented in the Management Control and Status Reports document.

At the completion of integration testing, the tests and their results are reviewed for assurance that the software component is ready for acceptance testing. The review results are documented in the Assurance Specification. Deficiencies and discrepancies are documented in discrepancy reports in the Management Control and Status Reports document and responsibility for resolution assigned.

If verification and validation and/or independent verification and validation has been specified in the Management Plan, then verification of the product against the Design sections of the Product Specification is conducted and findings documented in the appropriate section of the Assurance Specification. If preparation for validation was not complete, it is finished and documented in the appropriate section of the Assurance Specification. Any reports are documented in the Management Control and Status Reports document.

Metric information (as specified in the Management Plan) is collected for the tracking and evaluation of the information system and documented in the Management Control and Status Reports document.

4.3.5.4 Product Summary

Management Plan: Plan Updates
Product Specification:
- Software Component (post-integration test)
- Version Description Document
- User's Guide
- Training Materials
- Maintenance Manual

Assurance Specification:
- Integration Test Results
- Quality Assurance Specifications, Procedures, Criteria, and Results
- Quality Engineering Assurance Specifications, Procedures, Criteria, and Results
- Safety Assurance Specifications, Procedures, Criteria, and Results
- Security and Privacy Assurance Specifications, Procedures, Criteria, and Results
- Verification Specifications, Procedures, Criteria, and Results

Management Control and Status Reports:
- Lessons Learned
- Review Reports
- Status Reports
- Discrepancy Reports
- Engineering Change Proposals
- Performance/Metrics Reports

4.3.5.5 Phase Transition

The Software Integration and Test Phase concludes with the successful completion of the Test Readiness Review (TRR) of the software component. The Test Readiness Review is conducted to determine whether software acceptance test preparation is complete and to assure that the software component is ready for formal acceptance testing. A successful Test Readiness Review is usually predicated on the acquirer's determination that the acceptance test procedures and previous testing results form a satisfactory basis for proceeding into the Acceptance Testing Phase.

4.3.6 SOFTWARE ACCEPTANCE AND DELIVERY PHASE

The objectives of the Software Acceptance and Delivery Phase are to validate that the software component meets its documented requirements and the users' needs and to prepare the software for delivery.

4.3.6.1 Management Activities

The collected metric information is evaluated to determine the status of the software. This information is used for tracking and, when necessary, modifying the resource estimation and other project attributes. Identified risk areas are re-evaluated per the risk assessment process defined in the Software Management Plan. As a result of the above, modifications and updates to plans are made, as required, and documented in appropriate Management Plans and Management Control and Status Reports document.

Management participates in the product reviews, and/or evaluates the review and status reports, to determine the readiness to proceed to the next phase. Management is responsible for ensuring that all activities of this phase have been conducted and documented before final delivery of the software and initiation of the sustaining engineering activities.

The final accept or reject decision of the software component is the responsibility of management.

If discrepancy reports or change proposals are generated in this phase, management is responsible to ensure they are dispositioned and responsibility for resolution assigned.

4.3.6.2 Engineering Activities

The engineering activities include preparation of the software component for delivery and performing operational transition activities, such as training and generation of version-compatible User's Guide and Version Description sections of the Product Specification.

Metric information (as specified in the Development Plan) is collected for the tracking and evaluation of the software and documented in the Management Control and Status Reports document.

4.3.6.3 Assurance Activities

Acceptance test activities are conducted in conformance with the methods and approach designated in the Assurance Plan section of the Management Plan. The activities in this phase include formal testing of the software component against the requirements and the user scenarios.

If phased delivery is specified, then the acceptance testing is conducted on the software defined for the current delivery against the requirements defined for that delivery. The results from acceptance testing are documented in the Assurance Specification.

If verification and validation and/or independent verification and validation is specified in the Management Plan, then the appropriate verification activities and all validation testing are conducted. Results are documented in the appropriate sections of the Assurance Specification. Reports are documented in the Management Control and Status Reports document.

Acceptance test results and reports, along with any (independent) validation results and reports, are analyzed. An acceptance review is conducted and documented in a review report. Deficiencies and discrepancies are documented in discrepancy reports in the Management Control and Status Reports document, and responsibility for resolution is assigned.

Metric information (as specified in the Management Plan) is collected for the tracking and evaluation of the software and documented in the Management Control and Status Reports document.

4.3.6.4 Product Summary

Management Plan: Plan Updates
Product Specification:
- Software Component (post-acceptance test)
- Version Description (update)
- User's Guide and Training Materials (update)

Assurance Specification:
- Acceptance Test Results
- Quality Assurance Specifications, Procedures, Criteria, and Results
- Quality Engineering Assurance Specifications, Procedures, Criteria, and Results
- Safety Assurance Specifications, Procedures, Criteria, and Results
- Security and Privacy Assurance Specifications, Procedures, Criteria, and Results
- (Independent) Verification and Validation Results

Management Control and Status Reports:
- Lessons Learned
- Review Reports
- Status Reports
- Discrepancy Reports
- Engineering Change Proposals
- Performance/Metrics Reports

4.3.6.5 Phase Transition

The Software Acceptance and Delivery Phase concludes with the successful completion of the Functional Configuration Audit (FCA) and the Physical Configuration Audit (PCA), resulting in an accept or reject decision. The object of the Functional Configuration Audit and the Physical Configuration Audit is to validate that the actual performance of the software component as determined through test complies with the requirements specifications, and to identify the test report(s) and data which document results of acceptance tests.

4.3.7 SOFTWARE SUSTAINING ENGINEERING AND OPERATIONS PHASE

The objectives of the Software Sustaining Engineering and Operations Phase are to sustain the operational capabilities of the software component, to make "repairs" and upgrades within the context of the original concept of the software, and to conduct user training and support.

Upgrades, either outside the scope of the original concept or involving the major rework of the implementation, may be considered outside of the scope of sustaining engineering activities and, thus, should be addressed in the evolutionary acquisition of the software component. Sustaining engineering, as defined here, includes maintenance.

Sustaining Engineering and Operations is often conducted at the information system level. In such case, sustaining engineering of the software component will be conducted from the delivery of the software to the acquirer (i.e., the information system at the next higher level in system decomposition) until the information system itself enters its sustaining engineering and operations phase. Support to sustaining engineering and operations of the the information system may be required of the software component.

4.3.7.1 Management Activities

Review and approval of discrepancy reports and change proposals is conducted by management. Modifications and updates to plans are made and documented in appropriate Management Plans. Plans for change incorporation must adhere to the same acquisition and assurance requirements as originally identified for the software component classification level.

Management participates in the product reviews, and/or evaluates the review and status reports, to determine the readiness to deliver the next release of the software. Management is responsible for ensuring that all activities of this phase are conducted and documented.

If discrepancy reports or change proposals are generated in this phase, management is responsible to ensure they are dispositioned and responsibility for resolution assigned.

4.3.7.2 Engineering Activities

Technical evaluation of discrepancy reports and change proposals is performed. Changes to the software component are only implemented based on approved change requests. This requires iteration through the requirements, design, implementation, and testing phases of the life-cycle. The activities defined in those phases are performed, resulting in updates to the specified products.

In addition to supporting the operations of the information system, user and operator training may be required as an on-going services.

Metric information (as specified in the Management Plan) is collected for the tracking and evaluation of the software and documented in the Management Control and Status Reports document.

4.3.7.3 Assurance Activities

To maintain the integrity and quality of the software component, the same types and levels of assurance must be conducted during sustaining engineering as were performed during development (i.e., previous phases of the life-cycle). Reviews of all updated products are conducted and documented in review reports. Acceptance testing, verification and validation, and independent verification and validation activities are performed, as specified in the Management Plan. Regression testing is performed to assure that operational integrity is maintained. Test results are documented in the Assurance Specification.

If required by software changes, modification to specifications, criteria, test cases, and expected results may be made. This will require updates to the Assurance Specification.

Metric information (as specified in the Management Plan) is collected for the tracking and evaluation of the software and documented in the Management Control and Status Reports document.

4.3.7.4 Product Summary

Management Plan: Updates
Product Specification: Updates
Assurance Specification: Updates
Management Control and Status Reports:
- Discrepancy Reports
- Engineering Change Proposals
- Status Reports
- Review Reports
- Performance/Metrics Reports

4.3.7.5 Phase Transition

The Software Sustaining Engineering and Operations Phase concludes with the retirement of the software (or the information system of which the software is a component) or the transition to its next evolutionary phase.

Reviews conducted during the Sustaining Engineering and Operations Phase are dependent upon the types of changes required. Sustaining Engineering requires revisiting life-cycle phases. For each life-cycle phase revisited, the appropriate phase transition reviews are conducted.

4.4 Hardware Life-Cycle Definition

The hardware life-cycle consists of the following phases:

Hardware Concept and Initiation
Hardware Requirements
Hardware Design
- Architectural Design
- Detailed Design

Hardware Fabrication
Hardware Integration and Test
Hardware Acceptance and Delivery
Hardware Sustaining Engineering and Operations (Support)

This life-cycle usually is initiated for each hardware component. The hardware life-cycle is presented here in terms of variations from the information system life-cycle. In general, independent verification and validation, certification, and evolutionary acquisition activities are only conducted at the information system level, not at the component level. Therefore, activities and products related to these may not be applicable to hardware. In addition, sustaining engineering and operations may be conducted on the system as a whole; in such cases, the hardware provider supports this system level activity.

4.4.1 HARDWARE CONCEPT AND INITIATION PHASE

The objective of the Hardware Concept and Initiation Phase is analogous to the corresponding information system life-cycle phase.

Some of the activities for this phase may not be required due to their previous execution at higher nodes in the system decomposition. The hardware concept may have been fully defined at a higher level. Management planning for the Acquisition Planning section may be able to reference sections in higher-level documentation.

In this phase and all subsequent phases of the life-cycle:

- Lessons learned reports are completed
- Adherence to the life-cycle and documentation standards contained herein must be assured
- All products, including updates to previously baselined products, are placed under configuration management prior to their review

4.4.2 HARDWARE REQUIREMENTS PHASE

The objective of the Hardware Requirements Phase is analogous to the corresponding information system life-cycle phase. The hardware component activities and products for management, engineering, and assurance may differ from the information system activities in the following:

- Sustaining Engineering and Operations may be a system level activity, but supported by the hardware component
- Requirements are traceable to the next higher level design, either information system or hardware

The successful completion of the Requirements Review for hardware triggers transition to the next phase.

As with the Concept and Initiation phase, the management activities may result in references to sections in higher level documentation.

4.4.3 HARDWARE DESIGN PHASE

The Hardware Design Phase may be partitioned into two subphases, architectural design and detailed design, with a phase transition review at the conclusion of each.

4.4.3.1 Architectural Design

The objective of the Hardware Architectural Design Phase is analogous to the Information System Design Phase. During this phase the architecture of the hardware is developed. The activities and products for management, engineering, and assurance may differ in the following:

- If the hardware or portions of the hardware is to be acquired off-the-shelf, then selection and procurement preparation is conducted in this phase
- The design decomposition can only be into hardware sub-components or into hardware design elements
- Reuse/commonality and buy/build/modify plans for hardware are developed
- This phase is concluded with the successful completion of the Hardware Preliminary Design Review (PDR)

If the hardware design is specified in terms of lower level hardware subcomponents, then this hardware component enters an

implementation coordination phase (analogous to the information system implementation coordination phase) and life-cycles are instantiated for each hardware subcomponent. The requirements for this hardware component are allocated to the hardware subcomponents.

If the hardware design is specified in terms of hardware design elements (rather than major subcomponents), than this hardware component enters the detailed design phase, followed by the fabrication phase.

4.4.3.2 Detailed Design

The Hardware Detailed Design Phase is not directly analogous to any phase in the information system life-cycle. The objective of the Hardware Detailed Design Phase is to continue the design process to the assembly and unit level in preparation for hardware fabrication. The activities in this phase are only conducted at the lowest hardware component level of the decomposition tree and are dependent on buy/build/modify decisions.

4.4.3.2.1 Management Activities

The collected metric information is evaluated to determine the status of the hardware component. This information is used for tracking and, when necessary, modifying the resource estimation and other project attributes. Identified risk areas are re-evaluated per the risk assessment process defined in the Management Plan. Planning modifications and updates are made, as required, and documented in appropriate Management Plans and Management Control and Status Reports document.

If the hardware or portions of the hardware are to be acquired off-the-shelf, then selection and procurement preparation is conducted in this phase.

Participation in the product reviews, or evaluation of the review and status reports, is conducted by management to determine the readiness to proceed to the next phase. It is the responsibility of management to ensure all activities (engineering and assurance) of this phase have been conducted and documented before the fabrication activities of the next phase are initiated.

If discrepancy reports or change proposals are generated in this phase, management is responsible to ensure they are dispositioned and responsibility for resolution assigned.

4.4.3.2.2 Engineering Activities

Detailed design activities are conducted in conformance with the methods and approach designated in the Development Planning section of the Management Plan.

Hardware detailed design to the unit level is conducted during this phase for each hardware assembly. This design is documented in the Detailed Design section of the Hardware Product Specification.

Buy/build/modify decisions are made in this phase and any necessary procurement activities conducted. Incremental development and phased delivery decisions affect the scope of the design activity.

If the entire hardware component is acquired off-the-shelf as a single package, then detailed design activities, unit test development, and integration testing may be omitted. (The implementation phase would consist of final procurement activities in preparation for acceptance testing.)

Metric information (as specified in the Management Plan) is collected for the tracking and evaluation of the hardware component and documented in the Management Control and Status Reports document.

4.4.3.2.3 Assurance Activities

If the hardware is developed (rather than purchased off-the-shelf), then hardware unit test specifications, procedures, and criteria are generated and documented in the Unit Test section of the Assurance Specification.

If the hardware component is acquired off-the-shelf as a single package, then the hardware acceptance test cases are prepared in this phase as the integration testing activity is not required.

Other assurance activities as specified in the Assurance Planning section of the Management Plan are conducted, including reviews of the engineering and assurance products developed in this phase. Findings are documented in the Assurance Specification. Deficiencies and discrepancies are documented in discrepancy reports in Management Control and Status Reports document, and responsibility for resolution assigned.

Metric information (as specified in the Management Plan) is collected for the tracking and evaluation of the hardware component and documented in the Management Control and Status Reports document.

4.4.3.2.4 Product Summary

Management Plan: Plan Updates
Product Specification: Design Specification -- Detailed
Assurance Specification:
- Unit Test Specification, Procedures, and Criteria
- Quality Assurance Specifications, Procedures, Criteria, and Results
- Quality Engineering Assurance Specifications, Procedures, Criteria, and Results
- Safety Assurance Specifications, Procedures, Criteria, and Results
- Security and Privacy Assurance Specifications, Procedures, Criteria, and Results
- Acceptance Test Cases

Management Control and Status Reports:
- Lessons Learned
- Review Reports
- Status Reports
- Discrepancy Reports
- Engineering Change Proposals

4.4.3.2.5 Phase Transition

The Hardware Detailed Design Phase concludes with the successful completion of the Hardware Critical Design Review (CDR). The Critical Design Review is a technical review of the detailed design including interfaces. If the hardware is being developed incrementally, then the Critical Design Review is only for the current increment and its interfaces with existing increments.

4.4.4 HARDWARE FABRICATION PHASE

If the hardware's design is specified in terms of hardware subcomponents or is acquired as a single off-the-shelf package, then the objective of this phase is similar to the to the implementation coordination phase in the information system life-cycle.

If the hardware is being developed (i.e., built or modified), then the objective of this phase is to build the hardware component. Additional activities conducted in this phase for the development of the hardware component include:

- Hardware is produced from the detailed design and documented in the Product Specification
- Unit inspections and audits are conducted and documented in the appropriate review reports of the Management Control and Status Reports document

- Unit test cases are developed; tests are conducted and the results documented in the Assurance Specification

This phase concludes with peer reviews of the tested units.

4.4.5 HARDWARE INTEGRATION AND TEST PHASE

The objective of the Hardware Integration and Test Phase is analogous to the corresponding information system life-cycle phase. The activities and products for management, engineering, and assurance may differ in the following:

- A Hardware Maintenance Manual is developed
- Hardware units and/or acquired hardware packages are integrated, and integration testing is performed
- The product of this phase is the hardware component

Preliminary integration testing with other hardware components or software components (or against the interface design) at the same (or possibly higher) level in the information system decomposition tree (i.e. horizontal integration), although not required, is recommended during this phase or the following phase in preparation for system integration testing.

4.4.6 HARDWARE ACCEPTANCE AND DELIVERY PHASE

The objective of the Hardware Acceptance and Delivery Phase is analogous to the corresponding information system life-cycle phase.

Final acceptance of the hardware component may be contingent upon proof that the component can be successfully integrated into the information system (or higher level hardware component depending on the decomposition tree).

4.4.7 HARDWARE SUSTAINING ENGINEERING AND OPERATIONS PHASE

After acceptance and delivery of the hardware, sustaining engineering and operations support to the information system may be required. Sustaining Engineering and Operations may be conducted only at the information system node once the information system has reached that phase in its life-cycle.

4.5 Operational Procedures Life-Cycle

Operational Procedures are the manual procedural aspects of the information system (usually conducted by an "operator") which complement the hardware and software of an information system.

Early definition, interoperability with hardware and software, and implementation of these operational procedures are critical to the effectiveness of the information system. This section describes the management, engineering, and assurance activities necessary to support to the definition and assurance of these operational procedures.

The operational procedures life-cycle consists of the following phases:

Operational Procedures Concept and Initiation
Operational Procedures Requirements
Operational Procedures Design
Operational Procedures Implementation
Operational Procedures Evaluation and Training
Operational Procedures Sustaining Engineering and Operations

This life-cycle is instantiated for each operational procedures component. The operational procedures life-cycle is presented here in terms of variations from the information system life-cycle. In general, independent verification and validation, certification, and evolutionary acquisition activities are only conducted at the information system level, not at the component level. Therefore, activities and products related to these may not be applicable to operational procedures. In addition, sustaining engineering and operations may be conducted on the system as a whole; in such cases, the operational procedures provider supports this system level activity.

4.5.1 OPERATIONAL PROCEDURES CONCEPT AND INITIATION PHASE

The objective of the Operational Procedures Concept and Initiation Phase is analogous to the corresponding information system life-cycle phase.

Some of the activities allocated to this phase may not be required due to their previous execution at higher nodes in the system decomposition. The operational procedures concept may have been fully defined at a higher level. Management planning may be able to reference sections in higher-level documentation.

In this phase and all subsequent phases of the life-cycle:

- Lessons learned reports must be completed

- Adherence to the life-cycle and documentation standards contained herein must be assured
- All products, including updates to previously baselined products, are placed under configuration management prior to their review

4.5.2 OPERATIONAL PROCEDURES REQUIREMENTS PHASE

The objective of the Operational Procedures Requirements Phase is analogous to the corresponding information system life-cycle phase. The operational procedures component activities and products for management, engineering, and assurance may differ from the information system activities in the following:

- Sustaining Engineering and Operations may be a system level activity, but supported by the operational procedures component
- Requirements are traceable to the next higher level design

As with the Concept and Initiation phase, some of the management activities may result in references to sections in higher level documentation.

4.5.3 OPERATIONAL PROCEDURES DESIGN PHASE

The objective of the Operational Procedures Design Phase is similar to the Information System Design Phase. The operational procedures component activities and products for management, engineering, and assurance may differ from the information system activities in the following:

- Commonality plans for procedures are developed
- Detailed design of the procedures is performed
- Manual procedures specified for hardware and software are incorporated into the design of the operational procedures

4.5.4 OPERATIONAL PROCEDURES IMPLEMENTATION PHASE

The objective of the Operational Procedures Implementation Phase is to develop the operational procedures manual for the information system. Activities include:

- Procedures are developed from the detailed design and documented in the operational procedures manual section of the Product Specification

- Walkthroughs are conducted and documented in the appropriate Assurance Specification and review reports of the Management Control and Status Reports document
- Inspections and audits may be conducted and documented in the appropriate Assurance Specification and review reports of the Management Control and Status Reports document

The products of the Operational Procedures Implementation Phase are: the manual containing the procedures for the operators of the information system, the Version Description section, and training materials and users' guide sections of the Product Specification.

4.5.5 OPERATIONAL PROCEDURES EVALUATION AND TRAINING PHASE

The objectives of the Evaluation and Training phase are to evaluate the correctness and effectiveness of the procedures and to conduct training on operational use.

4.5.5.1 Management Activities

Identified risk areas are re-evaluated per the risk assessment process defined in the Information System Management Plan. As a result, modifications and updates to plans are made, as required, and documented in appropriate Management Plans and Management Control and Status Reports document.

Management participates in the product reviews, or evaluates the review and status reports, to determine the readiness to proceed to the next phase. Management is responsible for ensuring that all activities of this phase have been conducted and documented before final delivery.

If discrepancy reports or change proposals are generated in this phase, management is responsible to ensure they are dispositioned and responsibility for resolution assigned.

4.5.5.2 Engineering Activities

The engineering activities include final preparation of the procedures for delivery and performing operational transition activities, such as operator and user training.

4.5.5.3 Assurance Activities

The assurance activities in this phase include evaluation of the procedures against the requirements, including "testing" and assurance activities specified in the Management Plan.

Reviews are conducted periodically throughout the Evaluation and Training Phase and are documented in a review report. Deficiencies and discrepancies are documented in discrepancy reports, and responsibility for discrepancy resolution is assigned.

4.5.5.4 Product Summary

Management Plan: Updates
Product Specification:
- Operational Procedures Manual (post-evaluation)
- Version Description Document
- Operators Manual and Training Materials

Assurance Specification:
- Evaluation Specifications, Procedures, Criteria, and Results
- (Independent) Verification and Validation Results

Management Control Status Reports:
- Lessons Learned
- Review Reports
- Status Reports
- Discrepancy Reports
- Engineering Change Proposals
- Performance/Metrics Reports

4.5.5.5 Phase Transition

The Operational Procedures Evaluation and Training Phase concludes with the successful completion of the Operational Procedures Acceptance Review, resulting in an accept/reject decision.

4.5.6 OPERATIONAL PROCEDURES SUSTAINING ENGINEERING AND OPERATIONS PHASE

After acceptance and delivery of the operational procedures, sustaining engineering and operations support to the information system may be required. Sustaining Engineering and Operations may be conducted only at the information system node once the information system has reached that phase in its life-cycle.

4.6 Life-Cycle Documentation Products

Prior to the implementation phase of the life-cycle, most products are documents. The purpose of the documentation is to record information concerning the activities and decisions of that phase. There are four basic documents defined as the documentation set for each information system and each component in the system decomposition tree. The four basic documents are:

- Management Plan
- Product Specification
- Assurance Specification
- Management Control and Status Reports

The four basic documents can be supplemented with a "repository" of project-specific standards, procedures, and practices for such things as network protocols, graphics, and programming conventions.

In general, each document relates directly to a category of activities defined in the life-cycle definitions. Management activities are documented in the management plan; engineering activities in the product specification, and assurance (technical) activities in the assurance specification. The management control and status reports document is intended to provide an organization and logical home for all reports - management, engineering, and assurance. In general, the reports are written for management.

Each document in the document set may consist of one or more volumes. A mechanism called roll-out is used to define the organization of subordinate volumes while ensuring traceability. Figure 4-3 presents an example of roll-out.

The amount of information to be documented, and hence the number and size of physical volumes, is determined by program/project management.

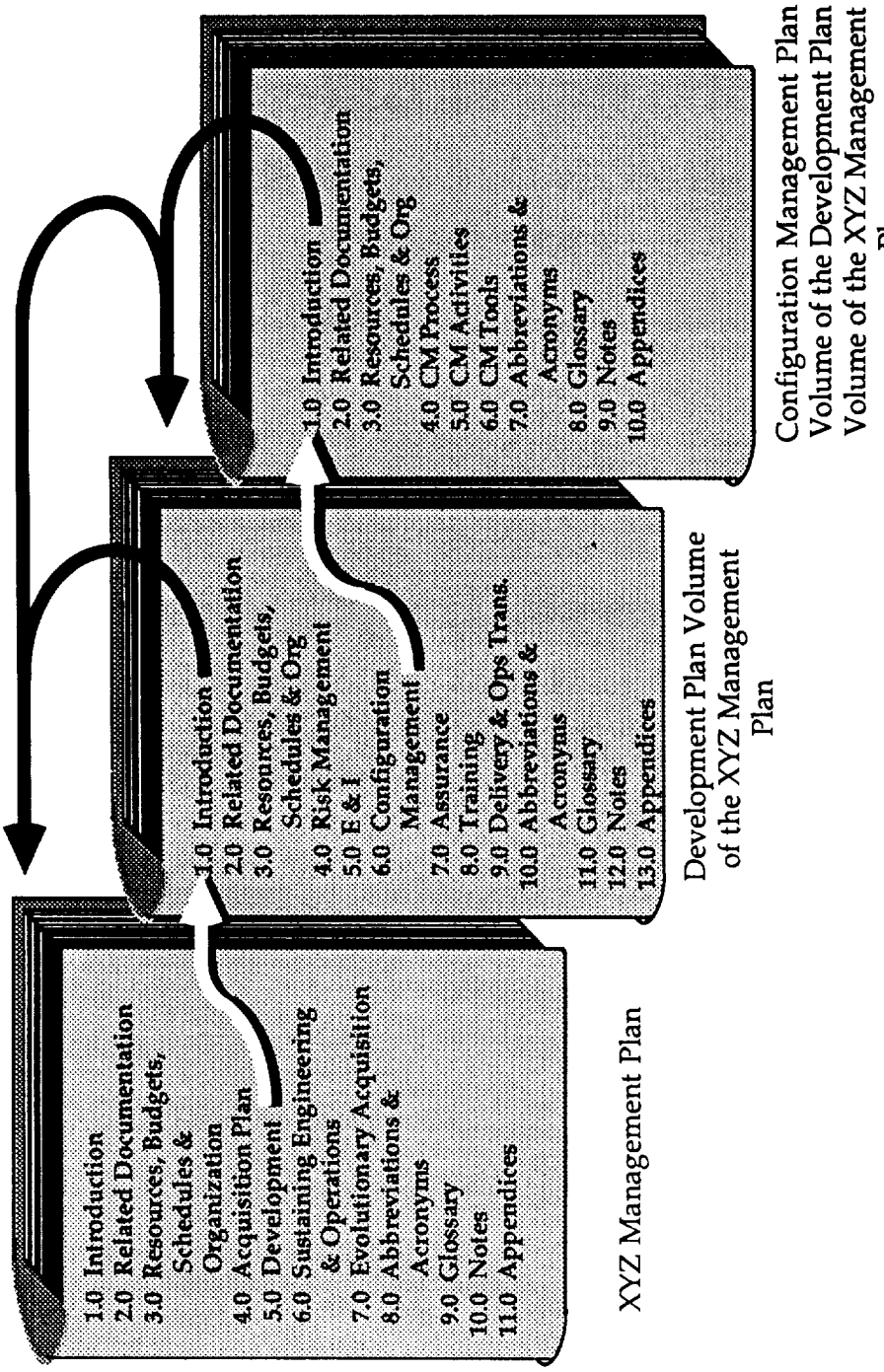

Figure 4-3. Example of Roll-Out of Document Sections into Volumes.

The actual documentation standards, associated rules, and the detailed Data Item Descriptions (DIDs) for the four document types are presented in volumes rolled-out from this document. The four volumes are:

- Management Plan Documentation Standard and Data Item Descriptions
- Product Specification Documentation Standard and Data Item Descriptions
- Assurance Specification Documentation Standard and Data Item Descriptions
- Management Control and Status Reports Documentation Standard and Data Item Descriptions

The major sections of each of the four documents is presented in the table below. Figures 4-4, 4-5, and 4-6 present the timeline for generation of these sections against the life-cycle.

MANAGEMENT PLAN
Acquisition Development Sustaining Engineering and Operations Evolutionary Acquisition
PRODUCT SPECIFICATION
Concept Requirements Design Version Description User and Operator Documentation Maintenance Manual
ASSURANCE SPECIFICATION
Quality Assurance Testing Quality Engineering Assurance Safety Assurance Security and Privacy Assurance Verification and Validation Certification
MANAGEMENT CONTROL AND STATUS REPORTS

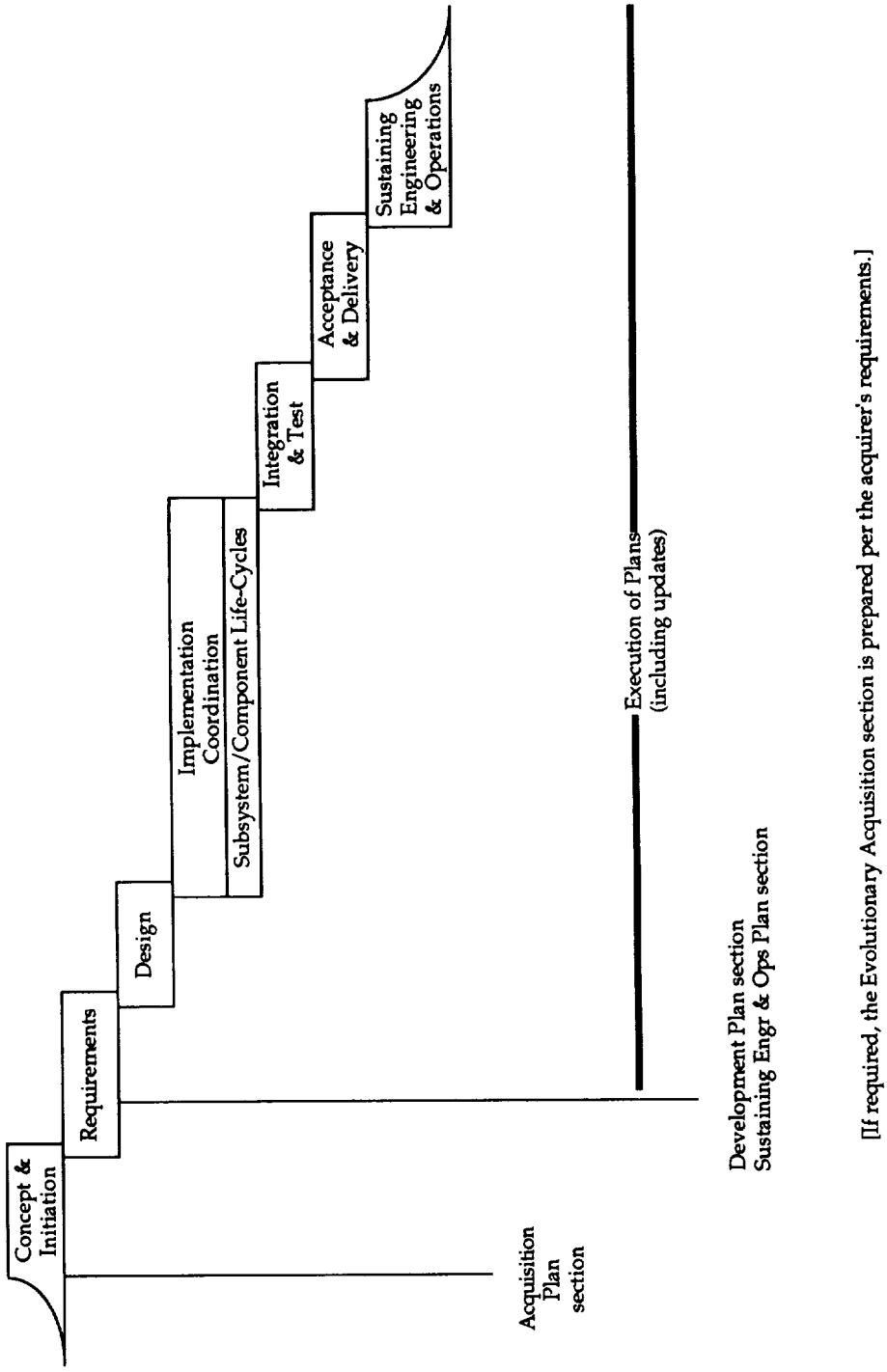

Figure 4-4. Management Plan Timeline.

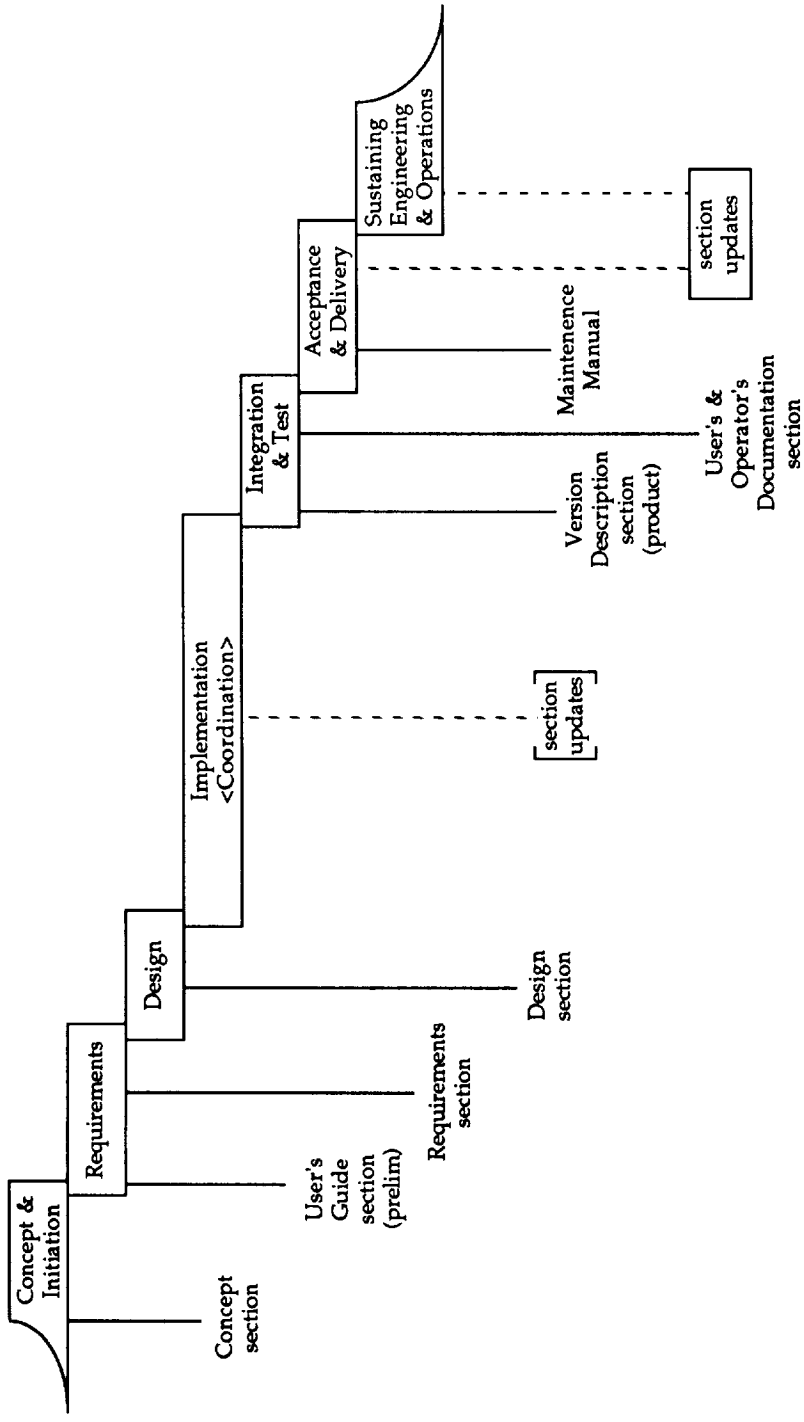

Figure 4-5. Product Specification Timeline.

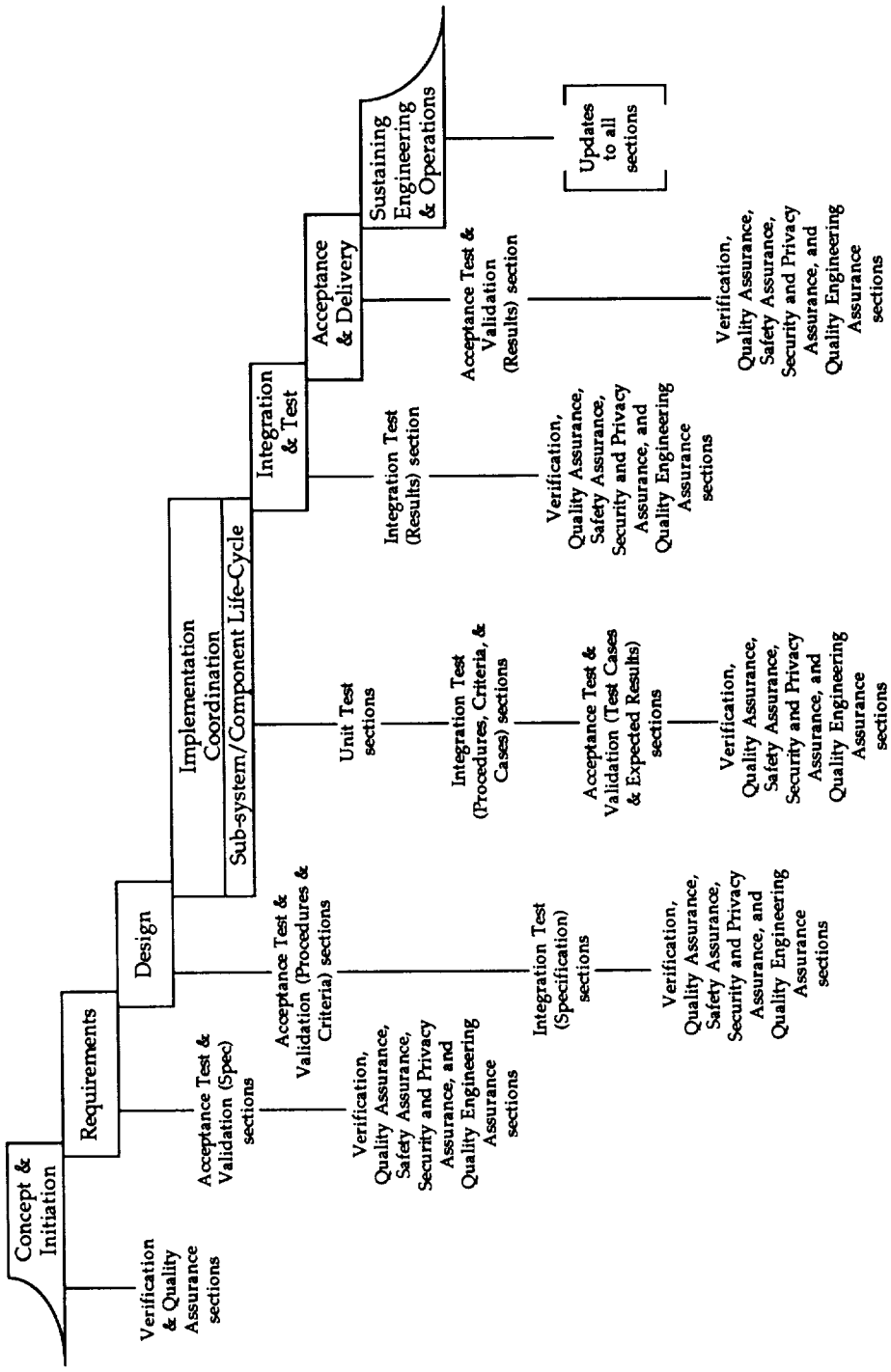

Figure 4-6. Assurance Specification Timeline.

4.7 Phase Transition Reviews

An essential part of the life-cycle model is the phase transition reviews. A phase transition review occurs at the end of each phase. As the sustaining engineering process is an iteration of the activities of previous life-cycle phases, these phase transition reviews must also be conducted as part of the sustaining engineering process. The major purposes of the phase transition reviews are to provide a focal point for: 1) the assurance activities associated with the current phase, and 2) the update of the management plan for the next phase. Figure 4-7 lists the phase transition reviews associated with each phase.

A phase transition review almost always produces a number of discrepancy reports and action items. If the number and criticality of issues to be resolved is low, then activities of the subsequent phase may be initiated in parallel with rework for the current phase. When the rework is complete, an informal review should be conducted to ensure the adequacy of the rework.

If the number or criticality of issues to be resolved is high, then major activities for the current (and possibly previous) phase may need to be repeated. No activities for the subsequent phase are initiated. A "delta" phase transition review should be conducted to ensure that all issues have been properly resolved.

The Assurance Planning sections of the Management Plan identify the review process and the responsible organizations. The review criteria and other technical specifications of the reviews including the results are documented in the Assurance Specification. Reports to management concerning the reviews are documented in the Management Control and Status Reports document. The review process, criteria, responsible organizations, and other descriptive details of phase transition reviews are dependent upon the assurance plans and assurance specifications for the information system or component under review. It is the responsibility of management to define, schedule, and execute these reviews.

Life-Cycle Phase	Information System	Software	Hardware	Op Procs
Concept & Initiation	Concept Review	Same	Same	Same
Requirements	Requirements Review	Same	Same	Same
Design	Design Review			Same
Architectural Design		Preliminary Design Review	Preliminary Design Review	
Detailed Design		Critical Design Review	Critical Design Review	
Implementation	————	Peer Review	Peer Review	Peer Review
Integration & Test	Test Readiness Review	Same	Same	Acceptance Review
Acceptance & Delivery	FCA/PCA (Acceptance Review)	Same	Same	
Sustaining Engr & Ops	(repeat all applicable reviews)	Same	Same	Same

Figure 4-7. Component Life-Cycle Review Variations.

4.8 Life-Cycle and Documentation Rules

For each information system, for each subordinate information system (subsystem), and for each hardware, software, and operational procedures component identified as a node in the information system decomposition tree, the following rules shall apply:

1) A life-cycle shall be instantiated and shall conform to the appropriate life-cycle model defined in Section 4.2, 4.3, 4.4, or 4.5. The description of the instantiation shall be contained in the management plan for that information system or component.

2) Each instantiated phase shall end with a phase transition review. The results of such a review shall be prepared and placed in the Assurance Specification document.

3) A documentation set of four documents shall be prepared for each information system and component. This set shall consist of a management plan, a product specification, an assurance specification, and a management control and status reports document.

The following rules associated with life-cycle determination and documentation shall apply:

1) Assurance activities shall be successfully accomplished before making the transition from the current phase to the next phase of the life-cycle.

2) The management plan shall be updated and reviewed as a necessary transition from the current phase to the next phase of the life-cycle.

3) The management plan shall define the roles and responsibilities of the acquirer's and providers' organizations.

4) The management, engineering, and assurance processes defined in the Management Plan shall be followed throughout the instantiated life-cycle.

Specific documentation standards and associated rules for the documentation set are contained in Section 4 of the four rolled-out volumes referenced in Section 2.2.

5.0 APPLICATION AND SUPPORT OF THE LIFE-CYCLE AND DOCUMENTATION STANDARDS

The guidelines supporting the documentation standards are contained in Section 5.1 of the four rolled-out volumes of this document (referenced in Section 2.2).

5.1 Guidelines for the Application of the Life-Cycle Standard

5.1.1 How to Instantiate a Life-Cycle

The life-cycles are defined in Section 4 as serial processes with precise boundaries and each phase occurring only once. While a simple information system or component can be acquired or developed in that manner, the large and complex systems that comprise the majority of the information systems or large, complex components require adaptations to these life-cycle models.

An initial version of the life-cycle instantiation is prepared early in the concept and initiation phase. When instantiating a life-cycle for a specific node (system or component), the system decomposition tree defined to that node must be taken into consideration. The life-cycle being instantiated must conform to the life-cycle definitions and adaptations, standards, schedules, and milestones, etc. of parent nodes in the system decomposition tree, as defined in the documentation sets for these parent nodes. The constraints imposed by these parent nodes must be considered during the instantiation of the life-cycle for this node.

Using the life-cycle model, phases that are appropriate to the development or procurement of the information system or component are determined. Often there are substantial iterations during the development of an information system or component. Sections 5.1.2 through 5.1.4 describe common life-cycle adaptations to support different types of iteration.

The instantiation of the life-cycle determines the gross level schedule and milestone layout (or vice versa). The actual phases and scheduling of the life-cycle impacts the work breakdown structure, reviews, schedules, and milestones for the node. Conversely, changes in the management plan can require changes in the instantiation of the life-cycle model. The description of the specific, adapted life-cycle to be used is documented in the management plan.

5.1.2 Phased Delivery Adaptation

Information system or component development often requires supplying multiple deliveries, usually with increasing capability, to the acquirer (or next higher level information system or component). Each delivery must pass the acceptance testing for that delivery prior to its release. This procedures is termed "phased delivery" and requires multiple iterations through many of the life-cycle phases. Figure 5-1 presents an example of the life-cycle model adapted for phased delivery of a software component.

The purpose of the phased delivery adaptation is to get some capabilities to the users (or next higher level information system or component) as early as possible. Each delivery should provide increased capability to the user. In general, for phased delivery, the scope and all requirements for the information system or component are defined during the requirements phase, though these may get refined later in the life-cycle through discrepancy reports and change proposals from users. Phased delivery requires that sustaining engineering and operations support begin at the time of the first delivery.

5.1.3 Incremental Development Adaptation

When the concept of "code a little, test a little" is desired to be employed within the development organization, the life-cycle may require an incremental development adaptation. The purpose of the incremental adaptation is to avoid the "big bang" approach to development and integration in which an attempt is made to integrate the entire information system or component at one time. In this adaptation, a single delivery of the information system or component is delivered to the users but that delivery is developed in increments. The architectural design is partitioned into specific increments. Each increment provides a predefined, but not necessarily complete, set of functional capabilities. An example of an adaptation of the basic software life-cycle for incremental development is shown in Figure 5-2.

A principal benefit of incremental development is that it provides visibility into the development to assess progress. Incremental development has been shown to decrease risk and to increase reliability and productivity in the development process. Therefore, use of incremental development is encouraged, even when phased delivery requirements also exist. Managers should be advised, though, that this can increase the configuration management support required during the development process.

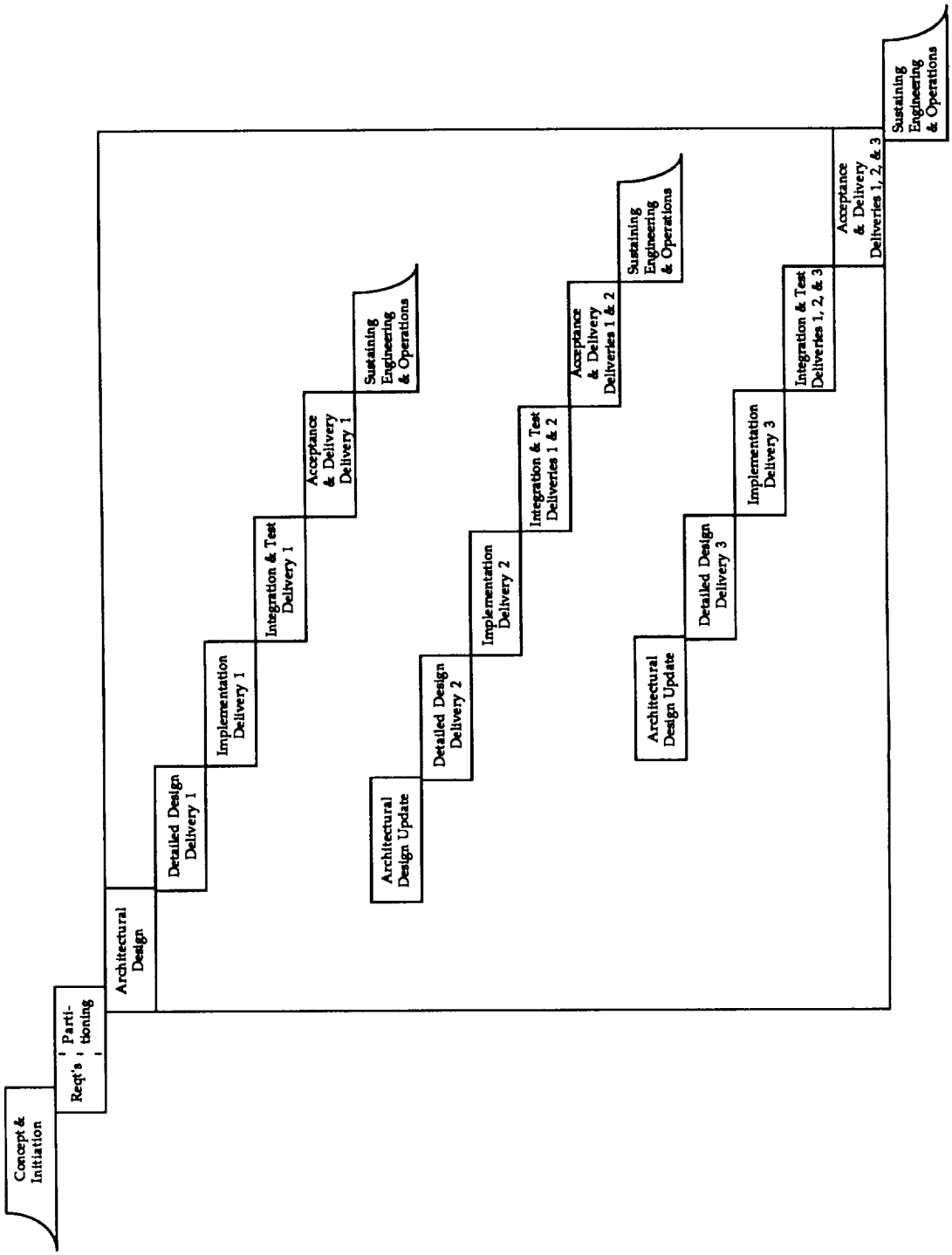

Figure 5-1. Example of a Software Component Phased Delivery Adaptation.

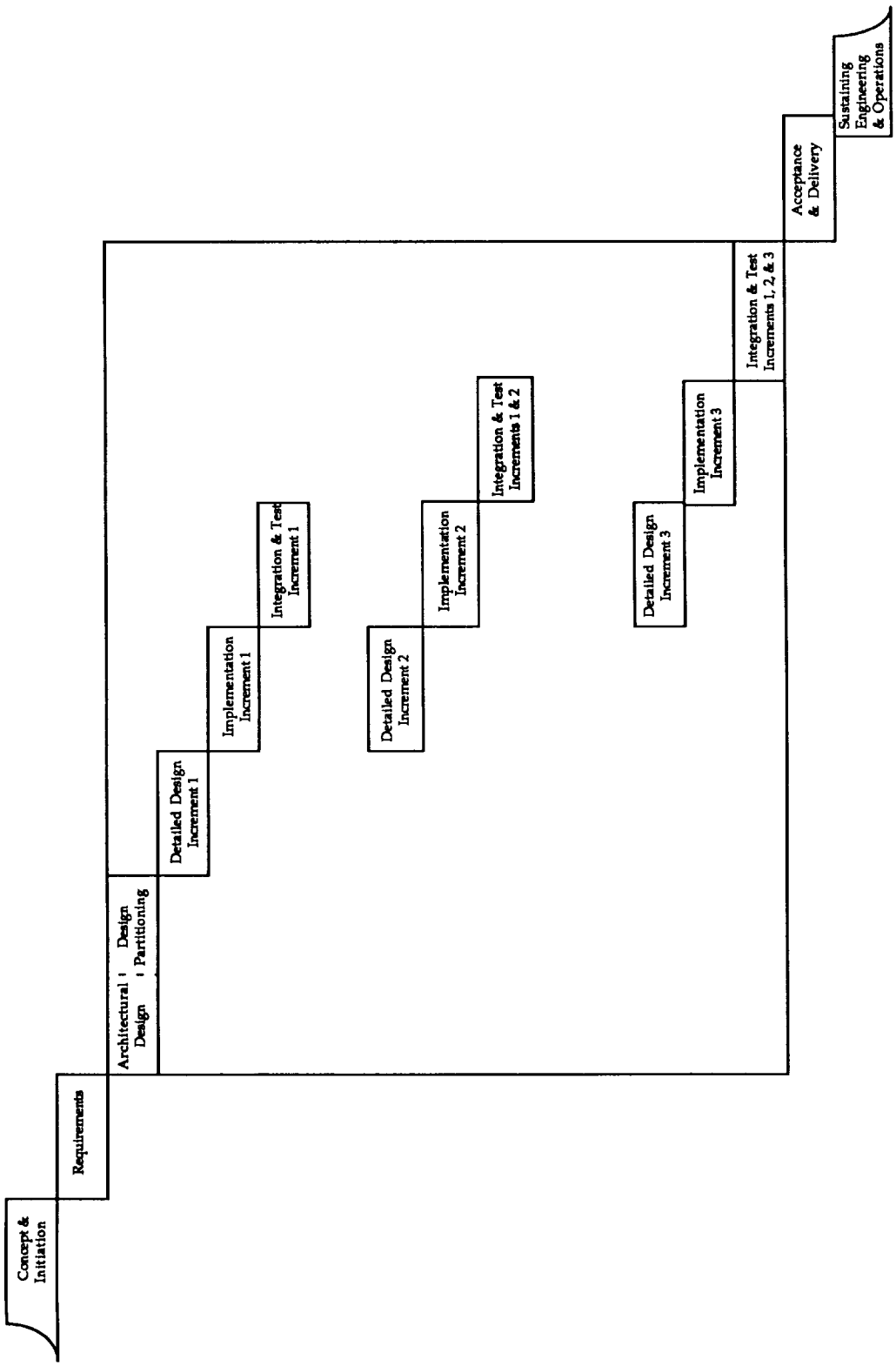

Figure 5-2. Example of a Software Component Incremental Development Adaptation.

Incremental development also can be used in conjunction with prototyping to focus on components or systems that have a high risk factor or are critical, or to explore alternative design and implementation approaches.

Incremental development is often used in conjunction with phased delivery; i.e., each delivery is developed incrementally. This requires partitioning of the requirements for phased delivery and of the design (consistent with the requirements partitioning) for incremental development. The combining of these adaptations requires detailed planning and a configuration management process.

5.1.4 Evolutionary Acquisition Adaptation

Evolutionary acquisition refers to multiple passes through the entire life-cycle for a specific information system or component. It usually refers to major upgrades to an information system or component for which major portions of the existing system may be used as inheritables. Evolutionary acquisition is usually only feasible for long-life systems for which new feasibility study and procurement activities are conducted. Requirements for the next evolution of a system or component are usually not known until after the current system or component has been in use for some time.

5.1.5 Interactions Between Life-Cycle Phases

While each phase usually has a distinct event that marks the end of the phase, the beginning of a phase does not usually wait for the completion of the previous phase. Often there exists a build-up period beginning during the previous phase and a phase-down period to work any action items or discrepancies from the reviews and other assurance activities of the phase. For example, the provider may begin the work of the next phase while the products of the previous phase are still in distribution for final review and comment. An example of such an adaptation is shown in Figure 5-3.

Note that while efforts may be started before the formal baselining of the products of the previous phase, the early start carries the risk that what is done may need to be redone as a result of the decisions resulting from the phase transition review at the end of the previous phase. Thus only areas where virtually little or no change is anticipated should be started early. The provider is held responsible for any cost or schedule growth resulting from early start of work having to be redone due to changes made during the completion process of the previous phase.

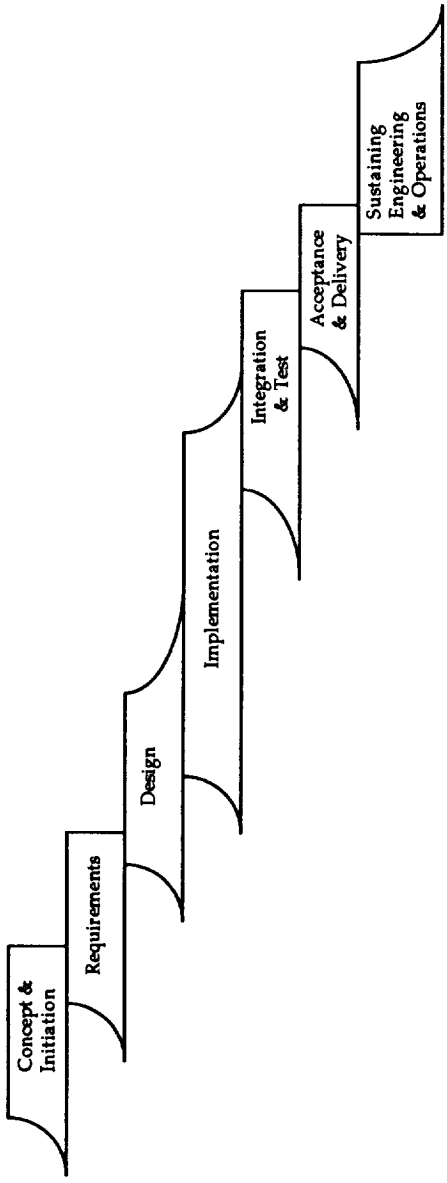

Figure 5-3. Software Life-Cycle Adapted for Phase Interaction.

5.1.6 Interactions Among Life-Cycles

The life-cycle presented in this document is designed to accommodate a system decomposition methodology. (See concepts presented in Section 3.4 of this document.) Based on that approach, information systems (or components) can impose life-cycle adaptation requirements on systems or components at lower levels in the decomposition. The interaction may become quite involved. For example, if an information system plans to incorporate incremental development into its development approach, then that may impose phased delivery requirements on its subsystems or components. The development manager must take this into consideration when determining the development approach and life-cycle adaptations to be employed in the development of a particular information system or component. An example of life-cycle interactions is depicted in Figure 5-4.

5.1.7 Adaptation for Prototyping

Certain techniques, especially if used in parallel to the production development, can impact the life-cycle adaptation. The development manager must determine what techniques are to be used in the development of the information system or component, determine exactly how these techniques are to be used, establish how these affect the life-cycle and products, and document this in the Development Plan section of the Management Plan.

For example, prototyping is a technique that can be useful in a number of different ways. It can be used for requirements analysis or for design trade-offs. It can involve evaluation by users or by the development team of various models of parts of the system or component. In any event, the use of a technique, such as prototyping, should tie back into the goals and products for the phase in which it is being used.

Prototyping is defined within the scope of this standard as a process (or method) used within the life-cycle to assess and/or reduce risk or to gain knowledge. Categories of prototypes sometimes referred to as interim or final are considered forms of phased delivery or incremental development and are covered under adaptation of the life-cycle for those development approaches. Categories of prototyping recognized within this standard (such as conceptual, functional, or performance) reflect either in which phase prototyping is being used or for which risk or knowledge area this activity is being performed.

How and when prototyping, or any other technique, is to be used for the development of an information system or component and any required adaptation of the life-cycle activities, products, and reviews is the responsibility of the development manager and is

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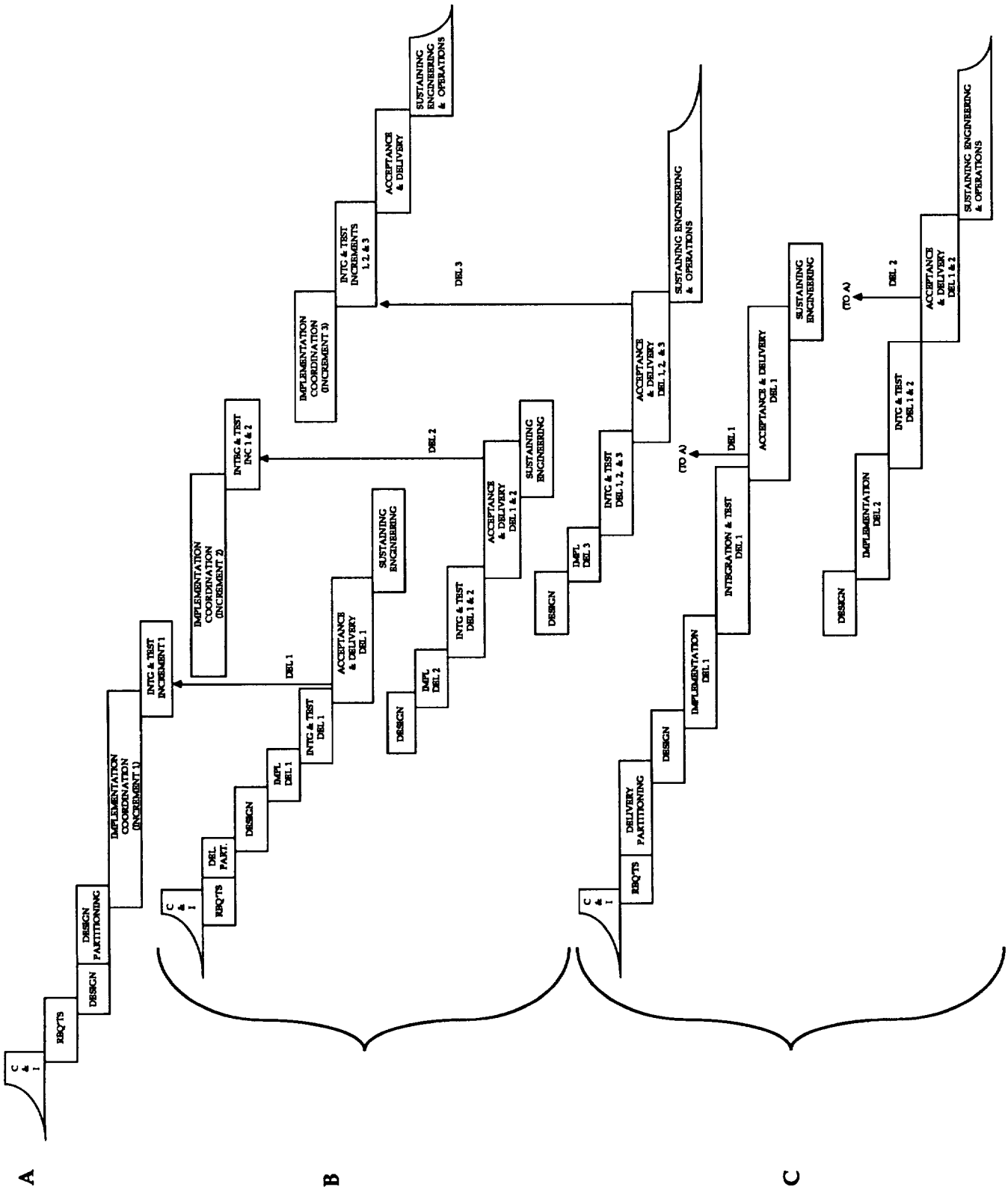

Figure 5-4. Life-Cycle Interaction Example.

documented in the Development Plan section of the Management Plan for that particular information system or component.

Prototyping as a process can be used anywhere within the life-cycle. It is usually used within a phase as a process or method used in engineering of the products of that phase. The prototyping process consists of three steps: Definition and Planning; Execution and Analysis; and Evaluation. The product of the prototyping process is a report, the results of which may be used within the products of that phase. The prototyping process may produce a number of by-products, including software, hardware, models, and systems. The re-use of any by-products (and their subsequent assurance, etc.) is a management issue and should be addressed in the management plan.

Activities of the Definition and Planning step of the prototyping process include specification of the risk, need, or issue to be addressed; formal statement of the problem; definition of expectations; specification of the evaluation criteria; and definition of the techniques to be used to perform the prototyping.

Activities of the Execution and Analysis step include selection and preparation of specific methods to be used to perform the prototyping process; execution, i.e., the simulation, emulation, etc.; and analysis of the results against the criteria. The Evaluation step is used to document the results of the analysis and of the prototyping process and present any trade-offs and recommendations.

Prototyping is a risk assessment and analysis method that may be applied within any phase of the life-cycle. Use of prototyping may be established early in the software life-cycle when trade analysis and risk conditions are identified. Or a decision to use prototyping may arise later in the life-cycle based the introducton of new technology or of a risk factor. In either event, the plan and goal of the prototyping activity should be defined within the management plan and the evaluation and results in a management control and status report. If the prototyping activity is a major effort, involving the development and/or procurement of a large hardware/software facility, then the facility should have its own development plan and related product and assurance specifications.

5.1.8 Adaptations for COTS

When an information system or component (or part thereof) is procured as a commercial-off-the-shelf (COTS) item, the instantiated life-cycle may be substantially abbreviated. In the optimum situation, when the entire system or component is procured off-the-shelf, only the following three phases might be required:

1) Concept and Initiation
2) Requirements
3) Acceptance and Delivery

In this adaptation, though, some activities identified in other life-cycle phases must be incorporated into these phases.

In the Concept and Initiation Phase, the need is scoped and based upon a quick inventory of the commercial marketplace, a decision is reached whether one or more commercial packages are available to meet the needs and that the selection of such a package is the best solution.

If the decision is negative (i.e., a COTS solution is not feasible), then a typical development process life-cycle must be defined and initiated. If the decision is positive (i.e., a COTS solution is feasible), then the Requirements Phase is begun. During the Requirements Phase, specifications for the procurement and criteria for the selection are developed, and a procurement process started and completed. Also, the acceptance test specifications, test cases, etc. are developed.

In the Acceptance and Delivery Phase, acceptance tests are conducted on the COTS item and, if successful, the item is accepted for delivery. Any training, if necessary, should be part of the delivery process and, therefore, the procurement. In this example, it is assumed that no sustaining engineering is required and that operations are either conducted by the acquirer or are a part of the activities of an encompassing information system or component.

Of course, the adaptation of the life-cycle model for a COTS procurement might be more involved. For example, the decision to obtain a commercial package might not be made until the Design Phase or a COTS item may be only one element of an information system or component. The important point is that the life-cycle model is adaptable to a wide range of applications including a COTS procurement. In adapting the life-cycle for a specific implementation, all life-cycle activities must be considered for their applicability.

5.2 Tools Supporting the Application and Use of the Life-Cycle and Documentation Standards

Management and engineering automated support environments may provide tools for the application and use of these standards. Tool support of these standards is the responsibility of the program/project.

6.0 ASSURANCE AND ENFORCEMENT OF THE LIFE-CYCLE AND DOCUMENTATION STANDARDS

If the SMAP information system life-cycle and documentation standards have been selected by program/project management as standards for an information system or component, then it is the responsibility of program/project management to assure and enforce these standards.

The standards assurance and enforcement process is an integral part of the assurance process for the information system or component. This process is addressed in the following ways:

1) As the assurance sections of the management plan are being prepared, proper emphasis should be applied to the enforcement and interpretation process of the standards.

2) When the selection and ordering of the phases for the instantiation of the life-cycle model is being reviewed, the life-cycle model provides a checklist for the reviewers.

3) As a quality assurance activity during the phase transition reviews indicated by the instantiation of the life-cycle model.

4) As explicitly called for within any assurance section of a plan. For example, the assurance planning section of the management plan could call for a special review at the end of the implementation phase to verify that all documentation was prepared according to the SMAP documentation standards.

It is the responsibility of any reviewer to be familiar with the particular aspects of the life-cycle and documentation standards that are applicable to the products or process(es) under review and to question any deviations from those standards.

The life-cycle model and detailed outline and contents specifications for documentation can be used by reviewers as a gross level checklist.

7.0 ABBREVIATIONS AND ACRONYMS

AR - Acceptance Review

CDR - Critical Design Review

COTS - Commercial off-the-shelf

DID - Data Item Description

DoD - Department of Defense

DRL - Data Requirements List

ECP - Engineering Change Proposal

EPROM - Erasable Programmable Read-Only Memory

FCA - Functional Configuration Audit

FMEA - Failure Modes and Effects Analysis

GFE - Government-furnished equipment

IV&V - Independent Verification and Validation

LRU - Line (or Lowest) Replaceable Unit

MTBF - Mean Time Between Failures

MTTR - Mean Time to Repair

NASA - National Aeronautics and Space Administration

NHB - NASA Handbook

NRCA - Nonconformance Reporting and Corrective Action

PCA - Physical Configuration Audit

PDR - Preliminary Design Review

PROM - Programmable Read-Only Memory

RFP - Request for Proposal

RID - Review Item Discrepancy

ROM - Read-Only Memory

RR - Requirements Review

SMAP - Software Management and Assurance Program

SOW - Statement of Work

SRM&QA - Safety, Reliability, Maintainability, and Quality Assurance

SSE - Software Support Environment of the Space Station Freedom Program

SSFP - Space Station Freedom Program

STD - Standard

TBD - To be determined (at a later date)

TMIS - Technical and Management Information System of the Space Station Freedom Program

TRR - Test Readiness Review

V&V - Verification & Validation.

WBS - Work Breakdown Structure

8.0 GLOSSARY

For terms not appearing in this glossary, refer to the IEEE Standard Glossary (as referenced in Section 2.2).

Acceptance Review - The phase transition review for the Acceptance and Delivery life-cycle phase.

Acquirer - An organization that acquires a capability, such as an information system.

Adaptation - The tailoring of the life-cycle and documentation standards (within the specifications of the rules and guidelines) for a specific program/project, information system, or component.

Allocation - The process of apportioning requirements at one level in the decomposition tree to the subsystems or subcomponents at the next lower level in the decomposition.

Assembly - A physical element of a hardware component consisting of one or more line replaceable units. A hardware component is composed of one or more physical assemblies.

Assurance - Includes any and all activities, independent of organization conducting the activity, that demonstrate the conformance of a product to a prespecified criteria (such as to a design or to a standard).

Assurance Specification - One of the four documents in the documentation set for an information system or component; it encompasses all the technical (i.e., non-planning) aspects of the assurance activities for an information system or component.

Baselining - The official acceptance of a product or its placement under configuration management as defined in the management plan.

Code Q - (NASA) Office of Safety, Reliability, Maintainability, and Quality Assurance

Component - 1) One of the three parts making up an information system: software, hardware, or operational procedures. 2) A portion of a higher-level component of the same type; e.g., a component of the software component (of an information system).

Critical Design Review - The phase transition review for the Detailed Design life-cycle phase.

Data Item Description - The table of contents and associated content description of a document or volume.

Design Element - An identifiable part of a component's architectural design.

Developer - The provider organization responsible for development of an information system or of a hardware, software, or operational procedures component.

Document - One of the four basic types of information for each information system or component: 1) Management Plan, 2) Product Specification, 3) Assurance Specification, and 4) Management Control and Status Reports Document. A document consists of one or more volumes.

Documentation Set - The four basic documents for each information system or component thereof.

Evolutionary Acquisition - The acquisition of an information system over a relatively long period of time in which two or more complete iterations of the life-cycle will be employed to revise and extend the system to such an extent as to require a major requirements analysis and therefore subsequent life-cycle iterations.

Increment - A pre-defined set of units integrated for integration testing by the development organization in response to incremental development plans.

Incremental Development - The process of developing a product before delivery in a series of segments. These segments remain internal to the development organization. The process is used to avoid the big bang approach to software development and help minimize risk. The segments are defined based on the design and documented in the design section of the product specification. The process leads to a single delivery unless used in conjunction with "phased delivery."

Independent Verification and Validation - Verification and validation performed by an independent organization. In general, this is intended to be independent of the development organization. For complete independence, the IV&V organization must report directly to or be funded directly by the acquirer.

Information System - 1) Any system composed of hardware, software, and operational procedures components required to process, store, and/or transmit data. 2) An integrated combination of software, hardware, and operational procedures components that provides a useful capability. An information system is generally software-intensive.

Inheritables - Existing software or hardware to be drawn upon in developing a new information system. The inheritables may be modified to meet the new system's requirements.

Instantiate - 1. To represent an abstraction by a concrete instance (e.g., heroes instantiate ideals). 2. Within Ada, the process of creating an instance of a generic subprogram or package.

Line Replaceable Unit - A hardware unit that is part of an assembly that is defined to be the lowest replaceable element of a hardware component. An assembly is composed of one or more LRUs.

Management Control and Status Reports Document - One of the documents in the documentation set for an information system or component; it represents a "logical" home for all report and request forms.

Management Plan - One of the four documentation set documents; it encompasses all planning information for an information system or component, including management, engineering, and assurance planning.

Partitioning - The process of determining the content for each delivery when using the phased delivery approach, or for determining the content of each segment when using incremental development.

Phase (of a life-cycle) - A set of activities and associated products and reviews that make up one step of a multi-step process for developing systems and their component. An information system life-cycle has seven standard phases: 1) Concept and Initiation; 2) Requirements; 3) Design; 4) Implementation Coordination (or Implementation or Fabrication); 5) Integration and Test; 6) Acceptance Test; and 7) Sustaining Engineering and Operations. In some cases, phase 3 contains multiple levels of design, such as architectural and detailed.

Phase Transition Review - The review at the end of a phase triggering transition to the next phase.

Phased Delivery - The process of developing and delivering a product in stages, each providing an increasing capability for an information system or component. The process may be employed to provide an early operational capability to users, for budgetary reasons, or because of risk, size, or complexity. Each delivery must undergo acceptance testing prior to release for operational use. The capabilities provided in each delivery are determined by prioritizing and partitioning

the requirements. This must be documented in the requirements section of the product specification.

Preliminary Design Review - The phase transition review for the Architectural Design life-cycle phase.

Product Specification - One of the four documentation set documents for an information system or component; it encompasses all the engineering and technical support information related to the development of an information system or component.

Prototyping - A process used to explore alternatives and minimize risks. Prototyping can be used in any life-cycle phase. The product of the process is a report. By-products (such as software, hardware, and models) of the process can be preserved for subsequent use.

Provider - An organization providing a capability to an acquirer; e.g., the developer or an organization providing independent verification and validation.

Quality Assurance - A subset of the total assurance activities generally focused on conformance to standards and plans. In general, these assurance activities are conducted by the SRM&QA organization.

Quality Engineering - The process of incorporating reliability, maintainability, and other quality factors into system, hardware, software, and operational procedures products.

Repository - A collection of standards, procedures, guides, practices, rules, etc. that supplements information contained in the documentation set for an information system or component. In general, the documentation set describes "what" is to be done and the repository provides the "how-to" instructions. A repository usually contains information that is applicable to multiple information systems and components.

Requirements Allocation - The process of distributing requirements of an information system or component to subordinate information systems (subsystems) or components.

Requirements Partitioning - The process of distributing requirements of an information system or component to different deliveries in support of phased delivery.

Requirements Review - The phase transition review for the Requirements life-cycle phase.

Review Item Discrepancy - A type of discrepancy report used when reviewing documentation.

Risk - The combined effect of the likelihood of an unfavorable occurrence and the potential impact of that occurrence.

Risk Management - The process of assessing potential risks and reducing those risks within dollar, schedule, and other constraints.

Roll-out - A mechanism for recording sections of a document in physically separate volumes while maintaining traceability and links. When using roll-out, a volume is subordinate to a parent document or volume.

Software Management and Assurance Program - Sponsored by NASA Code Q to foster more effective and productive software engineering methodologies.

Subsystem - In the information system decomposition context, a subsystem is an information system that is subordinate to a higher level information system and is parent to software, hardware, and operational procedures components, or to other (lower level) information systems.

Template - Within these Standards, a template is a DID framework used in the roll-out process for defining the specific format of a section rolled-out into a physically separate volume.

Test Readiness Review - The phase transition review for the Integration and Testing life-cycle phase.

Testing - The process of exercising or evaluating an information system or component by manual or automated means to demonstrate that it satisfies specified requirements or to identify differences between expected and actual results.

Tool - A hardware device or computer program used to help develop, test, analyze, or maintain another device or computer program or its documentation. (IEEE Std 729-1983)

Unit - An identifiable part of a detailed design. A level of decomposition for the purpose of physical design and implementation for a software or hardware component.

Validation - 1) Assurance activities conducted to determine that the requirements for a product are correct; i.e. to build the right product. 2) (IEEE Std 729-1983) The process of evaluating software at the end of the software development process to ensure compliance with software requirements.

Verification - 1) Assurance activities conducted to determine that a product is being built correctly in accordance with design and requirements specifications; i.e., to build the product right. 2) (IEEE Std 729-1983) "The process of determining whether or not the products of a given phase of ... development ... fulfill the requirements established during the previous phase."

Volume - A physically separate section of one of the four documents in a documentation set.

9.0 NOTES

None.

10.0 APPENDICES

None.

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