4.3 Requirements Management

4.3.1 Introduction to Requirements Management

The Requirements Management process, an element of System Engineering (SE), **is an activity that spans the program's entire lifecycle. Requirements Management iteratively identifies and refines the top-level requirements to successively lower levels, in concert with functional baselines and architectures, and synthesis of solutions established for the system of interest.** For the purposes of Requirements Management, a system or a product means any physical product or software being designed, developed, and/or produced, or any intangible product, such as a product describing a process or a service.

4.3.1.1 Requirements Definitions

4.3.1.1.1 Requirement

A requirement is ***an essential characteristic, condition, or capability that shall be met or exceeded by a system or a component to satisfy a contract, standard, specification, or other formally imposed document.***

4.3.1.1.2 Requirement Set

A Requirement Set is ***an aggregate of requirements for a system that specifies its characteristics in totality.***

4.3.1.1.3 Requirements Analysis

Requirements Analysis is ***the determination of system-specific characteristics based on analyses of customer needs, requirements, and objectives; missions; projected utilization environments for people products and processes; constraints; and measures of effectiveness.***

4.3.1.1.4 Requirements Management

Requirements Management is ***a process performed throughout a system's life to elicit, identify, develop, manage, and control requirements and associated documentation in a consistent, traceable, correlatable, verifiable manner.*** It ensures solution compliance with stakeholder needs and expectations using allocation, verification, and adaptation to and control of changes.

4.3.1.2 Process Description

4.3.1.2.1 Purpose

Requirements Management establishes a layered approach that defines the essential system characteristics and all system components required for the product's successful development, production, deployment, operation, and disposal. Successful completion of this process is measured by the acceptable transformation of stakeholder needs into discrete, verifiable, low-level requirements. The process identifies, clarifies, balances, and manages the entire requirements set through interactive dialogue with all stakeholders. Figure 4.3-1 shows the top-level process.

The Requirements Management process defines, collects, documents, and manages all requirements, including the complete requirements set consisting of the Service Level Mission Need (SLMN), the preliminary Program Requirements (pPR) and final Program Requirements (fPR), and the system and procurement specifications.

Executing this process results in an authorized, organized, and baselined set of requirements for a product. These requirements are presented as requirements sets, usually as requirements documents, to all other applicable SE and Federal Aviation Administration (FAA) processes. To effectively develop and manage system requirements, one must develop all requirements through this process.

4.3.1.2.2 Requirements Management Objectives

Requirements Management is an iterative process that:

- Identifies and captures the requirements applicable to the system
- Analyzes and decomposes the requirements into clear, unambiguous, traceable, and verifiable requirements
- Derives lower level requirements from higher level requirements in the system hierarchy
- Allocates the requirements to the appropriate component within the system hierarchy and/or to the appropriate organizational entities
- Establishes the method of verification for each requirement
- Ensures that the product complies with the requirements
- Manages, documents, and controls the requirements and changes to them in a traceable manner

Process:

Perform Requirements Management

ID No.: 4.3 (iCMM PA 1, 2)

Date: February 23, 2000

Revision Date: August 30, 2006

Next Higher Level Process:
Perform System Engineering

Process Owner:
System Engineering Council

Process Objective:
Identify and develop all requirements and ensure they are met throughout the product's lifecycle.

Inputs

a) Constraints, FAA Management Decisions, Government and International Regulations and Statutes, Legacy System, Needs, Standards, Technology
b) NAS Enterprise Architecture, SEMP, WBS
c) Concepts, Functional Architecture, OSED
d) Physical Architecture, Constraints, Product Definintion
e) Trade Study Reports
f) IRDs, ICDs
g) DARs, Constraints
h) Analysis Criteria, Constraints
i) Risk Mitigation Plans, Constraints
j) Baselines, Baseline Changes
k) Validation Reports, RVCD, VRTM
l) Constraints
m) SE Processes, SE Best-Practices Documentation (SEM), SEBOK

Providers

a) EXT
b) ITP
c) FA
d) SYN
e) TS
f) IM
g) SpecEng
h) IA
i) RSK
j) CM
k) V&V
l) LCE
m) MSE

PROCESS TASKS

Beginning Boundary Task

Identify/capture requirements

- Analyze and decompose requirements
- Derive requirements
- Allocate requirements
- Establish verificaion methodology
- Manage requirement changes

Ending Boundary Task

Analyze verification data

Lifecycle Phase

☑ Mission Analysis

☑ Investment Analysis

☑ Solution Implementation

☑ In-Service Management

☑ Disposal

Outputs

a) Requirements
b) RVCD
c) Planning Criteria
d) Constraints
e) Tools/Analysis Requirements
f) Concerns/Issues
g) VRTM
h) SOW

Customers

a) EXT, ITP, FA, SYN, TS, IM, SpecEng, IA, RSK, CM, V&V, LCE
b) EXT, SYN, SpecEng
c) ITP
d) TS
e) IA
f) RSK
g) V&V
h) EXT

Figure 4.3-1. Requirements Management Process-Based Management Chart

4.3.1.3 Management

The Requirements Management process bridges integrated product development system stages. The products are baselined in accordance with the milestones established in the Integrated Program Plan for the applicable project. Prerequisites for successful performance of the process are:

- Empowering a requirements analysis team with the authority and mission to execute the process
- Assigning an experienced team leader knowledgeable in SE principles and committed to the standard SE methods documented herein
- Assigning team members that are experienced and knowledgeable in relevant engineering, manufacturing, operational, specialty engineering, and support disciplines
- Establishing the criteria for decision making and any supporting tools
- Completing relevant training of team members in using this process and relevant tools
- Defining the formats of the output deliverables from this activity

4.3.1.4 Requirements Management Process Flow

Requirements Management is an iterative process that works with Functional Analysis and Synthesis to produce requirements. The process begins with the identified need and repeats through successively more detailed layers until requirements are detailed enough for their intended purpose. Figure 4.3-2 illustrates the FAA Requirements Management process flow that starts with the National Airspace System (NAS) Concept of Operations (CONOPS) and ends with the System Specification that will be used for system acquisition.

Starting from the NAS and NAS Enterprise Architecture, the initial Functional Analysis produces the System CONOPS. The functions described in the System CONOPS are the first inputs to the Identify and Capture requirements step of the Requirements Management process. These functions, along with the performance and nonfunctional requirements, are formed into the first system requirements and documented in the SLMN. At this point in the process, there is insufficient detail in the requirements to synthesize a physical architecture, so the synthesis step is not performed.

After the SLMN is completed during the first pass though the requirements process, the System CONOPS is further decomposed using the Functional Analysis process, as constrained by the requirements defined in the SLMN. This level of functional analysis produces the first level of the functional architecture and is used to refine the SLMN-level requirements into the initial requirements that are documented in the pPR. The pPRs are used to define the first version of the physical architecture during the Synthesis process.

The process then repeats to produce the fPR. The functional architecture, which is constrained by the pPR requirements, is decomposed. The fPRs are then decomposed from the functional architecture, which is constrained by the pPR-level physical architecture. The pPR-level physical architecture, which is refined by the fPR requirements, is used to derive the physical architecture at the fPR level.

The process then repeats a final time to produce the System Level Specification. The functional architecture, which is constrained by the fPRs, is decomposed. The System Specification requirements are then developed from the functional architecture, which is constrained by the fPR-level physical architecture. The fPR-level physical architecture, which is refined by the System Specification requirements, is used to derive the physical architecture at the System Specification level.

At any time during the process, the functions and requirements at a higher level can be revisited and reworked as necessary. These changes will then propagate downward through the process until the lower levels reflect the changes.

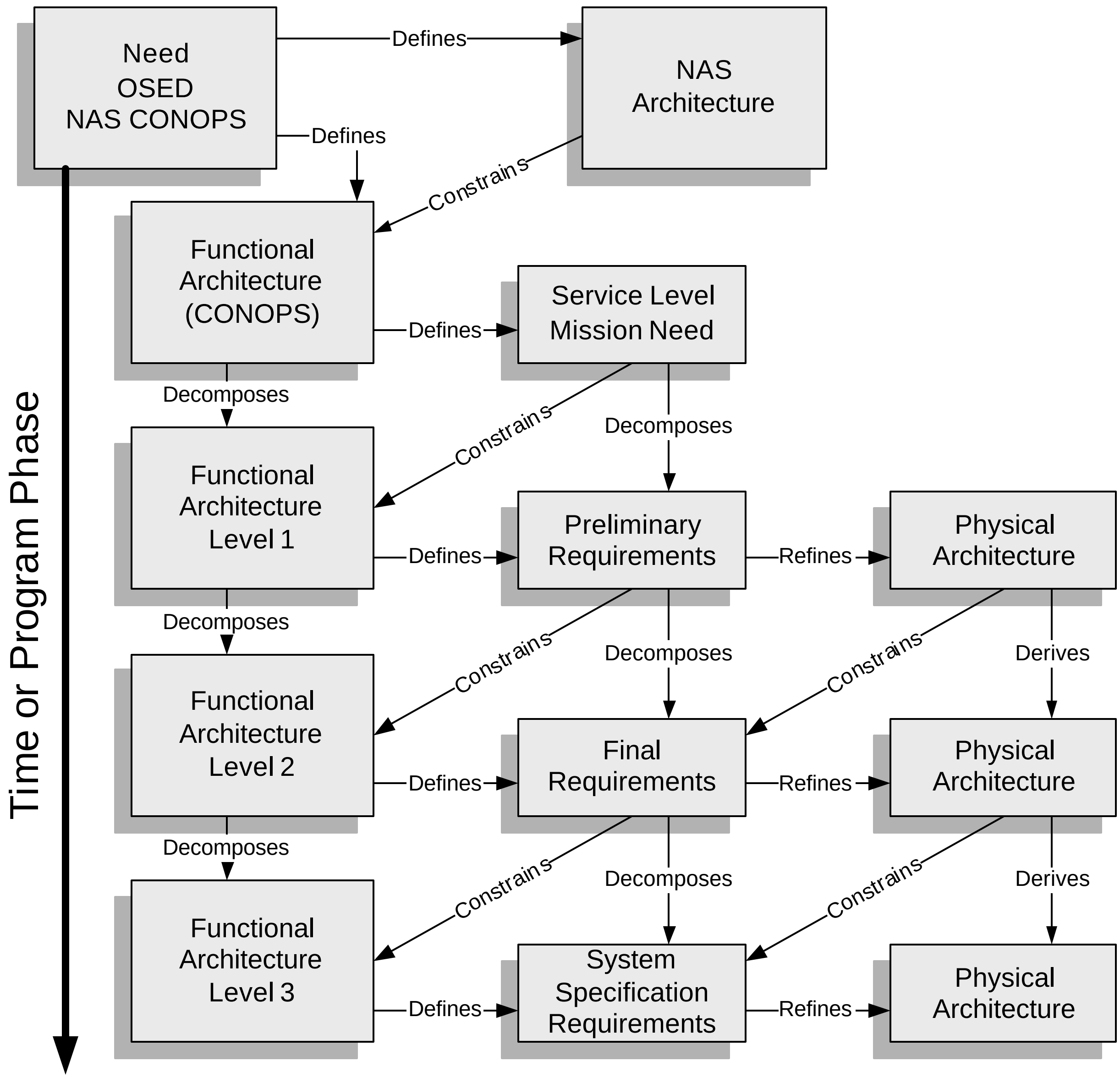

Figure 4.3-2. Requirements Management Process Flow

4.3.2 Inputs to Requirements Management

An input to the Requirements Management process **is information received during the process.** Inputs are classified according to their source, shown in Figure 4.3-3 to be either external or internal. External inputs come from sources outside SE. Internal inputs come from the other SE processes described in this manual.

Input requirements are comprehensive and defined for both system products and system processes, including the eight lifecycle functions of development, manufacturing, verification, deployment, operations, support, training, and disposal. Requirements Management is an iterative process that flows from a high level to a low level of requirements (as shown in Figure 4.3-2 above). Therefore, some of the inputs described in the following subsections may be inputs to one stage of the requirements development process and outputs of other stages.

All requirements sources described are inputs at one point in the process and are captured. The inputs to the Requirements Management process are described in the following subsections.

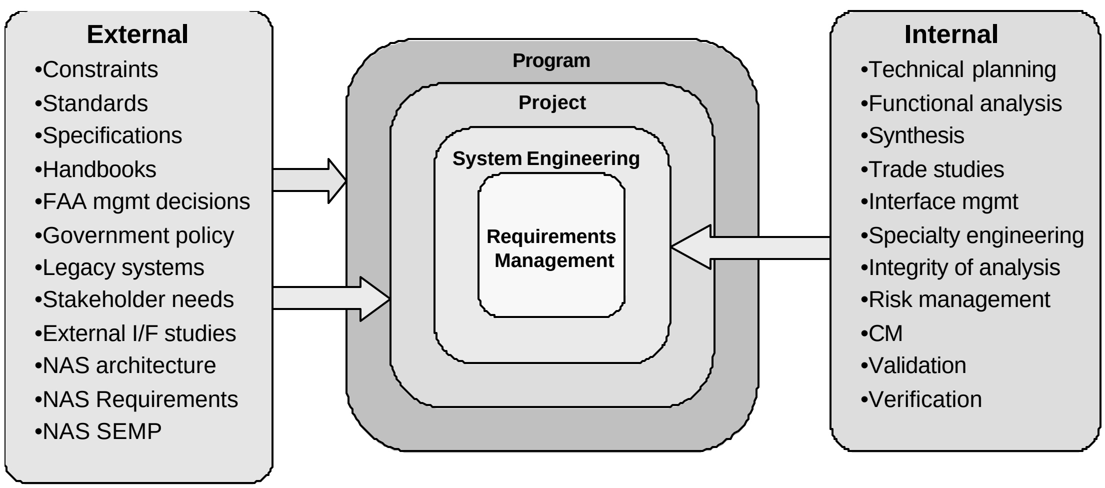

Figure 4.3-3. Input Sources to Requirements Management

4.3.2.1 External Inputs

External inputs come to the Requirements Management process from outside SE's boundaries.

4.3.2.1.1 Constraints

A Constraint is ***an internal or externally imposed boundary condition that places limits within which the system or process must remain.***

4.3.2.1.1.1 External Constraints

External constraints, including guidelines and assumptions, are identified. External constraints are imposed from outside the project or system boundaries. External conditions under which the mission is to be performed and systems developed are described. The conditions may include performance, technology, use of infrastructure, and labor/management agreement constraints. Additional assumptions concerning programmatics, technology, and environments that may be required are captured.

4.3.2.1.1.2 Internal Constraints

Internal constraints—including assumptions, guidelines, and program-specific constraints—are identified. Internal constraints are imposed from within the project or system boundaries but outside of the SE process boundary. Program-specific conditions under which the mission is to be performed and systems developed are described. The conditions may include performance, technology, and use of infrastructure constraints. Additional assumptions concerning programmatics, technology, and environments that may be required are captured.

4.3.2.1.2 Standards, Specifications, and Handbooks

Specified government standards, external standards, and general specifications or handbooks to be used on the program are identified. The most common standards, specifications, and handbooks used in FAA requirements management appear in Appendix G.

4.3.2.1.2.1 Standards

A standard is ***a document that establishes engineering and technical requirements for processes, procedures, practices, and methods that have been adopted as standard.*** Standards may also establish requirements for selection, application, and design criteria for material. The FAA, Department of Defense (DoD), and other U.S. Government agencies, as well as the RTCA, international organizations, and commercial standards organizations publish standards.

4.3.2.1.2.1.1 RTCA Standards

The RTCA publishes standards as Minimum Operational Performance Standards (MOPS) and Minimum Aviation System Performance Standards (MASPS).

4.3.2.1.2.1.1.1 Minimum Operational Performance Standards

The MOPS contain performance requirements for avionics. The standards describe typical equipment applications and operational goals and establish the basis for required performance and test procedures for verification under a common set of standards. Definitions and assumptions essential to proper understanding are provided, as well as installed equipment tests and operational performance characteristics for equipment installations. The MOPS also provide information that explains the rationale for equipment characteristics and stated requirements.

4.3.2.1.2.1.1.2 Minimum Aviation System Performance Standards

The MASPS address the user-level service requirements used to qualify the system for operational acceptance and to allocate requirements for the subsystems (including avionics). The standards provide information that explains the rationale for system characteristics, operational goals, requirements, and typical applications.

4.3.2.1.2.2 Specifications

A specification is ***a document prepared specifically to support an acquisition that clearly and accurately describes the essential technical requirements for purchased material or products and the criteria for determining whether the requirements are satisfied.*** The FAA, DoD, and other U.S. Government agencies; international organizations; and commercial standards organizations publish specifications.

4.3.2.1.2.3 Handbooks

A handbook is ***a guidance document that contains information or guidelines for use in design, engineering, production, acquisition, and/or supply management operations.*** These documents present information, procedural and technical use data, or design information related to processes, practices, services, or commodities. Handbooks provide industry with reference materials that help to standardize FAA assets. Use of handbooks is optional unless required by a specification or contract document. The FAA, DoD, and other U.S. Government agencies; international organizations; and commercial standards organizations publish handbooks.

4.3.2.1.2.4 Federal Aviation Administration Orders

An FAA order is ***a permanent directive on individual subjects or programs that apply to the FAA. It directs action or conduct using action verbs.*** Orders also prescribe policy, delegate authority, and empower and/or assign responsibility for compliance with stated requirements or direction. Orders empower or direct only FAA personnel and cannot obligate contractors. Thus, orders are not used in contract documents. They are not referenced in requirements documents but are used as inputs with the potential to generate requirements.

4.3.2.1.2.5 National Airspace System Master Configuration Index

NAS-MD-001, "National Airspace System Master Configuration Index," lists all baselined systems, equipment, and software currently operational or under procurement for the National Airspace System (NAS) with current approved baseline documentation. FAA and contractor personnel use NAS-MD-001 to identify configuration items and documentation requiring NAS Change Proposals (NCP).

4.3.2.1.3 Federal Aviation Administration Management Decisions

Management decisions that are imposed on the system from the national, department, or agency level are captured.

4.3.2.1.4 Government Policy

4.3.2.1.4.1 Government Regulations and Statues

Government statutes and military and civilian regulations impacting the system are identified, including requirements incorporated into Executive orders and legislation (e.g., safety or security requirements). These requirements also include government standards that have been mandated as part of a contract.

4.3.2.1.4.2 International Policy

The International Civil Aviation Organization (ICAO) develops and publishes international Standards and Recommended Practices (SARP). An ICAO standard is any specification for physical characteristics, configuration, material performance, personnel, or procedure that is applied uniformly for the safety or regulation of international air navigation and to which the international aviation community conforms. An ICAO-recommended practice is identical to a standard except that it is not considered necessary—only desirable.

4.3.2.1.4.3 Federal Aviation Administration Policy

This category covers all FAA agencywide management decisions and policy requirements imposed by FAA agencywide mandate. The category may include technical, operational, acquisition, financial, and other requirements. FAA policy is invoked using the FAA Directives System, as described in FAA Order 1320.1, "FAA Directives System."

4.3.2.1.4.4 Acquisition Management System

New or revised directions and limitations established by the Acquisition Management System (AMS) are identified.

4.3.2.1.5 Legacy Systems

Requirements from past and current systems are captured and analyzed for applicability. Data for legacy systems are in FAA specifications and technical instruction books.

4.3.2.1.6 Stakeholder Needs

4.3.2.1.6.1 National Airspace System Concepts of Operations Document

The NAS Concepts of Operations (CONOPS) document provides a CONOPS from the perspectives of NAS users and service providers. It is the basis for an incremental benefits-driven approach toward NAS evolution. The document is arranged in a phases-of-flight approach, including Flight Planning, Surface, Arrival/Departure, En Route, and NAS Management. It is the source document for all NAS operational requirements.

4.3.2.1.6.2 Service Level Mission Need

The SLMN is the first document to translate the NAS CONOPS into the needs and requirements of the users and service providers. It identifies the decision factors relevant to a capability shortfall or a technological opportunity to satisfy a mission more efficiently or effectively. The SLMN justifies, in rigorous analytical terms, the need to resolve a shortfall in services required by its users and service providers or to explore a technological opportunity for more efficient and effective mission performance. The SLMN identifies the mission area, needed capability, current capability, capability shortfall, impact to users and service providers if the shortfall is not resolved, benefits, timeframe for resolving the shortfall, criticality of the mission, and resource estimate.

4.3.2.1.6.3 Operational Scenarios

Operational scenarios provided by the user describe how the CONOPS is implemented. The scenarios may include interactions with the environment and other systems, human tasks and task sequences, and physical interconnections with interfacing systems or products. They may be incorporated into the SLMN or provided as a separate document.

4.3.2.1.6.4 Requirements Document

A Requirements Document is ***a collection of requirements and related information or attributes presented in a user-defined format.***

The document establishes the operational framework and performance baseline and traces Functional Analysis to the NAS CONOPS and the SLMN; it also is the primary source document for the system-level requirements. This document is the principal force driving the search for a realistic and affordable solution to the mission need. The pPR document is developed early in the process by the sponsoring organization. It primarily provides a set of requirements that are used to evaluate the chosen alternatives. The document translates the need in the SLMN into initial top-level requirements that address such concerns as performance, supportability, physical and functional integration, human integration, security, test and evaluation, implementation and transition, quality assurance, configuration management, and in-service management. The pPR document does not describe a specific solution to a mission need. It is recommended that the document not preclude leasing, commercial, or nondevelopment solutions. The fPR document defines exactly the operational concept and requirements that are to be achieved and is the basis for evaluating the readiness of resultant products and services to become operational. The fPR document details the functional and performance requirements of the chosen alternatives and, when baselined, constitutes the functional baseline. The fPR document is the basis for developing the system-level specification.

The various requirements documents are developed in an iterative process that starts with the basic CONOPS and progresses through the SLMN, pPR, fPR, and eventually to the system level specification. Due to this iterative nature of the Requirements Management process, any of the requirements documents can be ***both an input to and an output of the process***.

4.3.2.1.7 External Interface Studies

System external interface studies and analyses that characterize and define the interfaces between the system and external environment are reviewed or conducted. These studies identify functional and physical characteristics between two or more elements that are provided by different agencies; they also resolve problems. Topics include issues, option assessments, impact assessments, interfaces and connections, sources of interferences, and configuration options.

4.3.2.1.8 National Airspace System Requirements

4.3.2.1.8.1 NAS Systems Requirements Specification (NAS-SR-1000)

This FAA document defines the NAS Level operational requirements and is the approved baseline document for operational requirements for the NAS. The document serves as a basis to perform studies and analysis and to identify engineering concepts to satisfy operational requirements. It also serves as a source document for system level specification preparation.

4.3.2.1.8.2 NAS Design Specification (NAS-DD-1000)

This baselined FAA document defines the NAS Level functional architecture, including basic NAS elements, sub-elements, subsystems, and their interrelationships.

4.3.2.1.8.3 NAS System Specification (NAS-SS-1000)

This baselined FAA document defines functional, performance, design, construction, logistics, personnel and training, documentation, verification, and interface requirements for the NAS.

4.3.2.2 Internal Inputs

Internal inputs come to the Requirements Management process from inside SE's boundaries and include inputs for all other SE processes (as shown in Figure 4.3-3 above). Execution of the other SE processes may generate constraints that impact the Requirements Management process. These constraints are identified and provided as inputs to the Requirements Management process and may result in derived requirements in step 3 (subsection 4.3.3.3 below) of the process.

4.3.2.2.1 Integrated Technical Planning

The Requirements Management planning section of the Implementation Strategy and Planning document (ISAP) and the System Engineering Management Plan (SEMP) (see Integrated Technical Planning (Section 4.2)) specify the tasks, products, responsibilities, and schedules for managing requirements throughout product development. It details the total effort for managing requirements. This work includes "Step 1: Identify and Capture Requirements" (subsection 4.3.3.1 below); "Step 2: Analyze and Decompose Requirements" (subsection 4.3.3.2); "Step 3: Derive Requirements" (subsection 4.3.3.3); "Step 4: Allocate Requirements" (subsection 4.3.3.4); and "Step 6: Manage Requirements Changes" (subsection 4.3.3.6).

4.3.2.2.1.1 NAS Enterprise Architecture

The NAS Enterprise Architecture is a strategic and evolutionary plan for modernizing the NAS that supports investment analysis tradeoffs. It defines and delivers the services that meet aviation industry and public needs by decomposing the services into capabilities that are the functions and activities necessary to deliver a service. Each capability is defined by the operational improvements that deliver the capabilities. Each operational improvement is defined in terms of the mechanisms required to provide each step. Finally, each mechanism is defined in terms of the people, systems, and support activities provided by the procuring office. The NAS Enterprise Architecture presents a comprehensive design that shows each major mechanism within the NAS, including interfaces and data flows. Using a documented design with traceable requirements as the foundation for the architecture not only provides a complete picture of the NAS, but it also provides a roadmap for implementing future enhancements.

4.3.2.2.1.2 System Engineering Management Plan

The SEMP relates the technical requirements to program requirements, providing the structure to guide and control requirements management activities to achieve the SE objectives consistent with a top-level management plan for the program.

4.3.2.2.1.3 Work Breakdown Structure (WBS)

The WBS provides a logical structure for developing the requirements.

4.3.2.2.2 Functional Analysis

4.3.2.2.2.1 Concept of Operations

A CONOPS is ***a description of what is expected from the system, including its various modes of operation and time-critical parameters.*** The CONOPS is obtained from the Functional Analysis process (Section 4.4). The CONOPS document communicates overall quantitative and qualitative system characteristics to the user, buyer, developer, and other organizational elements. The CONOPS aids in requirements capture and communicates the need to the developing organization. The CONOPS describes the existing system, current environment, users, interactions among users and the system, and organizational impacts. A CONOPS is essentially a top-level narrative Functional Analysis and is the basis for developing the SLMN.

4.3.2.2.2.2 Functional Architecture

Every function required to satisfy a system's operational needs is identified and defined. Once defined, the functions are used to define system requirements, and a functional architecture is developed based on the identified requirements. The process is then taken to a greater level of detail, as the identified functions are further decomposed into subfunctions, and the functional architecture and requirements associated with those functions are each decomposed as well. This process is iterated until the system has been completely decomposed into basic subfunctions, and each subfunction at the lowest level is completely, simply, and uniquely defined by its requirements. In this process, the interfaces between each of the functions and subfunctions are fully defined, as are the interfaces within the environment and external systems. The functions and subfunctions are arrayed in a functional architecture to show their relationships and internal and external interfaces.

The functional architecture includes a definition of the functions that the system needs to perform and is developed into Primitive Requirements Statements (PRS). "Step 2: Analyze and Decompose Requirements" (subsection 4.3.3.2 below) of the Requirements Management process develops these PRSs into Mature Requirements Statements (MRS).

4.3.2.2.2.3 Operational Services and Environmental Description

The Operational Services and Environmental Description (OSED) is a comprehensive, holistic description of the services, environment, functions, and mechanizations that form a system's characteristics. It consists of everything inside and outside the system that affects system performance and that is affected by system operation or both. Functional Analysis (Section 4.4) fully describes the OSED.

The OSED is used as a source to derive lower level requirements. It describes many system characteristics that are nonfunctional, such as environments, and that are not described in the functional architecture. Nonfunctional requirements are derived from the OSED in "Step 3: Derive Requirements" (subsection 4.3.3.3 below).

4.3.2.2.3 Synthesis

4.3.2.2.3.1 Physical Architecture

The physical architecture allocates requirements to the physical hardware and/or software during the Synthesis process (Section 4.5). If requirements conflicts are discovered during the development of the physical architecture, those requirements are cycled back through the Requirements Management process for evaluation, which may result in conducting a trade study (see Section 4.6), reallocating the requirement, or deriving lower-level requirements. The RAM describes requirements allocation.

4.3.2.2.3.2 Constraints

Constraints that are discovered during synthesis—including cost, schedule, programmatic, technology, and so forth—that will have an impact on requirements are returned to Requirements Management for input into the requirements process. The constraints identified in synthesis may introduce derived requirements. These derived requirements (Step 3: Derive Requirements (subsection 4.3.3.3)) may be developed through Synthesis (Section 4.5) and are generally not provided by external sources, such as the user, service provider, or government agencies.

4.3.2.2.4 Trade Studies

Trade Studies (Section 4.6) may be conducted within and across functions to support decisions during any stage of the system's lifecycle. They quantify through metrics the consequences of opting for various system alternatives, traceable to stakeholder requirements that may be imposed by the requirements development process. They support allocating performance requirements and determining requirements or Design Constraints; they are also used in evaluating alternatives. Trade Studies usually result in derived requirements that are developed into MRSs in "Step 2: Analyze and Decompose Requirements" (subsection 4.3.3.2).

4.3.2.2.4.1 Trade Study Reports

Trade Study Reports identify requirements that are affected by the results of each trade study (see Section 4.6). The new, changed, or derived requirements flow through the entire Requirements Management process and may result in changes to the requirements baseline. Trade Study Reports document the results of feasibility assessments and communicate derived requirements to the Requirements Management activity.

4.3.2.2.4.1.1 Feasibility Assessments

The Feasibility Assessment may be conducted to assess the difficulty in achieving program goals within the Constraints. Assessment results consider various aspects, such as technical, cost, and schedule, across the lifecycle. It provides information on the expectations for success, considering identified technology development needs in view of program and mission schedule and cost constraints. It also assesses the range of costs and benefits associated with several alternatives for solving a problem.

4.3.2.2.4.1.2 Derived Requirements

Derived requirements ("Step 3: Derive Requirements" (subsection 4.3.3.3)) may be developed through Trade Studies (Section 4.6) and not provided by external sources, such as the user, service provider, or government agencies. Derived requirements are returned to Requirements Management for analysis and possible inclusion in the requirements baseline.

4.3.2.2.5 Interface Management

The inputs from Interface Management (Section 4.7) identify, describe, and define interface requirements to ensure compatibility between interrelated systems and between system elements.

4.3.2.2.5.1 Interface Requirements Document

The Interface Requirements Document (IRD) defines requirements associated with external physical and functional interfaces between the particular system and other associated system(s).

4.3.2.2.5.2 Interface Control Document

The Interface Control Document (ICD) is a design document that describes the detailed, as-built implementation of the functional requirements in the IRD.

4.3.2.2.6 Specialty Engineering

Specialty Engineering (Section 4.8) defines and evaluates a system's specific areas, features, or characteristics. Specialty Engineering supplements the design process by defining these characteristics and assessing their impact on the program. Specialty Engineering studies often find characteristics that create a need for new or different requirements or a conflict between two or more requirements. The Specialty Engineering process develops the new or changed requirements, which become inputs to the Requirements Management process through the Design Analysis Report.

4.3.2.2.6.1 Design Analysis Reports

Design Analysis Reports (DAR), which document the results of a specific Specialty Engineering analysis with rationale, are inputs to the Requirements Management process. Each DAR contains a description of the system's special characteristics, a list of existing requirements that have undergone the Validation and Verification process (Section 4.12), residual risks, and candidate requirements derived from Specialty Engineering analysis.

The rationale supplementing the DARs includes the scope, ground rules, assumptions, constraints, methods, and tools applicable to the analysis.

4.3.2.2.6.2 Constraints

Constraints that are discovered conducting specialty engineering analysis—including cost, schedule, programmatic, technology, and so forth—that will have an impact on requirements are returned to Requirements Management for input into the requirements process. The constraints identified in Specialty Engineering may introduce derived requirements. These derived requirements (Step 3: Derive Requirements (subsection 4.3.3.3)) may be developed through

Specialty Engineering and are generally not provided by external sources, such as the user, service provider, or government agencies

4.3.2.2.7 Integrity of Analysis

4.3.2.2.7.1 Analysis Criteria

If the Requirements Management process requires an analysis or selection of a tool, Analysis Criteria for that analysis or selection are captured. The Analysis Criteria for conducting a required analysis is in the Analysis Management Plan (AMP).

4.3.2.2.7.2 Constraints

Any constraints driven by tool selection, skill requirements, or other programmatic considerations documented in the AMP are furnished to the Requirements.

4.3.2.2.8 Risk Management

4.3.2.2.8.1 Risk Mitigation Plans

The Risk Management (Section 4.10) process analyzes Concerns and Issues that any SE process identifies. Risk Mitigation Plans that result from risk analysis become inputs to the Requirements Management process. Requirements that present a risk are processed through the Requirements Management process for reanalysis, rederivation, and reallocation as needed.

4.3.2.2.8.2 Constraints

Constraints that are discovered in conducting risk management activities—including cost, schedule, programmatic, technology, and so forth—that will have an impact on requirements are returned to Requirements Management for input into the requirements process. The constraints identified in Risk Management may introduce derived requirements. These derived requirements may be developed through Step 3: Derive Requirements (subsection 4.3.3.3).

4.3.2.2.9 Configuration Management

4.3.2.2.9.1 Baselines

The Configuration Management process (Section 4.11) establishes baselines. After the responsible authority approves the baselines, Requirements Management updates and maintains the baseline requirements set.

4.3.2.2.9.2 Baseline Changes

Changes to the baselined requirements set are captured from the Configuration Management process (Section 4.11). "Step 6: Manage Requirements Changes" (subsection 4.3.3.6) inserts the baseline changes into the requirements set.

4.3.2.2.9.3 Configuration Status Accounting Reports

Configuration Status Accounting Reports are captured from the Configuration Management process (Section 4.11). "Step 6: Manage Requirements Changes" (subsection 4.3.3.6) uses these reports to maintain a status accounting of all requirements.

4.3.2.2.10 Validation

The Validation process (Section 4.12) determines if the requirements produced by the Requirements Management process are sufficiently correct and complete. Requirements that are not validated are captured and resubmitted to the Requirements Management process.

4.3.2.2.10.1 Validation Report

The Validation Report summarizes the results of the Validation process (Section 4.12) and communicates the Validation Table to the Requirements Management process.

The Validation Report contains:

- Summary of validation results
- Description of the system and program
- Validation methodology used
- Unvalidated requirements
  - List of nonconforming requirements
  - Recommendations for correction of nonconforming requirements
- Validation Table
- Discussion of trends and patterns of failure, evidence of systemic failings, and emerging threats to system services

4.3.2.2.10.1.1 Validation Table

The Validation Table lists all requirements and describes:

- If a requirement has been validated
- Where the requirement may be found
- Source of validation
- Corrective action to be taken if necessary
- Corrective action owner

Table 4.12-1 in Validation and Verification (Section 4.12) is an example of a Validation Table. The completed table is in the requirements document and is the basis for the Verification process.

4.3.2.2.11 Verification

The Verification process (Section 4.12) determines that the design solution satisfies applicable requirements.

4.3.2.2.11.1 Verification Requirements Traceability Matrix

The Verification Requirements Traceability Matrix (VRTM) is the heart of the Verification process. A Verification Requirement specifies the strategy or method used to verify each requirement, and the VRTM lists the Verification Requirements. The VRTM defines how each requirement (functional, performance, and design) is to be verified, the stage in which verification is to occur, and the applicable verification levels. The VRTM establishes the basis for the verification program. The Requirements Management process initiates the VRTM and sends it to the Verification process, which returns the VRTM to Requirements Management when verification has been completed.

4.3.2.2.11.2 Requirements Verification Compliance Document

The Requirements Verification Compliance Document (RVCD) provides evidence of compliance for each requirement at all levels and to each VRTM requirement. The flow down from the requirements documents to the VRTM completes the full requirements traceability. Compliance with all requirements ensures that the system-level requirements have been met. The RVCD defines, for each requirement, the verification methods and corresponding compliance information. The results of the Verification process (Section 4.12), including evidence of completion, are recorded and documented in the RVCD. It is recommended that the RVCD contain information regarding the results of each verification activity, as well as a description and disposition of conformance, nonconformance, conclusions, and recommendations. Compliance information provides either the actual data or a reference to the location of the actual data that shows compliance with the requirement. The document also includes a section that details any noncompliance. It is recommended that this section also specify appropriate reverification procedures. The Requirements Management process captures noncompliant requirements, leading to a decision on disposition of these requirements.

4.3.2.2.12 Lifecycle Engineering

4.3.2.2.12.1 Constraints

Constraints provided by Lifecycle Engineering to Requirements Management elements are Earned Value Management variances associated for each phase of the system lifecycle. These metrics are used to report cost, schedule, and technical performance associated with each service level. The constraints identified in Lifecycle Engineering may introduce derived requirements. These derived requirements may be developed through Step 3: Derive Requirements (subsection 4.3.3.3).

4.3.3 Requirements Management Process Steps

The following steps are necessary to perform Requirements Management:

- Identify and Capture Requirements
- Analyze and Decompose Requirements
- Derive Requirements

- Allocate Requirements
- Establish Requirements Verification Methods
- Manage Requirements

4.3.3.1 Step 1: Identify and Capture Requirements

4.3.3.1.1 Introduction

This step identifies, prioritizes, and extracts all written directives, including documented stakeholder negotiations/discussions, and internally derived requirements that are relevant to the particular stage of the system lifecycle.

This activity is performed on the entire system, including any requirements that are known at this stage about how the system will perform during its lifecycle and any constraints imposed on the system design/production by stakeholders and internal functions (i.e., manufacturing, product support, agency-level policies, suppliers).

4.3.3.1.2 Scope

The scope of the requirements set includes sufficient specification of all the system functions and all the external interfacing systems, including the system environment. This step may require considering a wider domain than the immediate physical boundary of the product and its components. Different boundaries may need to be defined for different states, modes, and capabilities. Refinement of these boundary definitions is an iterative process that occurs as more information is discovered about the true nature of the required system functions and performance.

4.3.3.1.3 Detailed Step 1 Description

Figure 4.3-4 describes the flow of the Identify and Capture Requirements step.

4.3.3.1.3.1 Step 1.1: Define Stakeholder Needs

Stakeholder needs are defined and quantified, and stakeholder needs in the FAA come from the operational stakeholder in the form of:

- CONOPS
- SLMN
- pPR or fPR

They are transformed into baselined requirements sets at a successively lower level through iteration of the Requirements Management process. It is recommended that the definition of stakeholder needs be balanced with an analysis of their effects on the overall system design and performance as well as on human engineering; knowledge, skills, and abilities; availability; reliability; safety; and training requirements of the humans required to support lifecycle processes. Stakeholder needs include:

- What the system is to accomplish (functional requirements)
- How well each function is to be performed (performance requirements)

- The operational and ambient environment in which the system is to be operated
- Constraints under which the system is to be developed or operated (e.g., funding, cost or price objectives, schedule, technology, non-developmental and reusable items, physical characteristics, and hours of operation per day)

4.3.3.1.3.2 Step 1.2: Define Project and Corporate Constraints

Project and corporate constraints that impact design solutions are identified and defined. The NAS Enterprise Architecture may also impose long-range planning constraints through the approved capabilities and operational improvements.

4.3.3.1.3.2.1 Project Constraints

Project constraints include:

- Existing approved specifications and baselines
- Updated NAS Enterprise Architecture operational improvements
- Updated NAS Enterprise Architecture segments and mechanisms
- Availability of automated tools
- Required metrics for measuring technical progress
- Constraints derived from other SE processes, including cost, schedule, programmatic, technology, and design constraints, and Earned Value Management variances

4.3.3.1.3.2.2 Corporate Constraints

Corporate constraints include:

- Management decisions from the Joint Resources Council or other management review
- FAA-wide general specifications, standards, handbooks, and guidelines
- FAA policy directives
- Established lifecycle processes
- Physical, financial, and human project resources

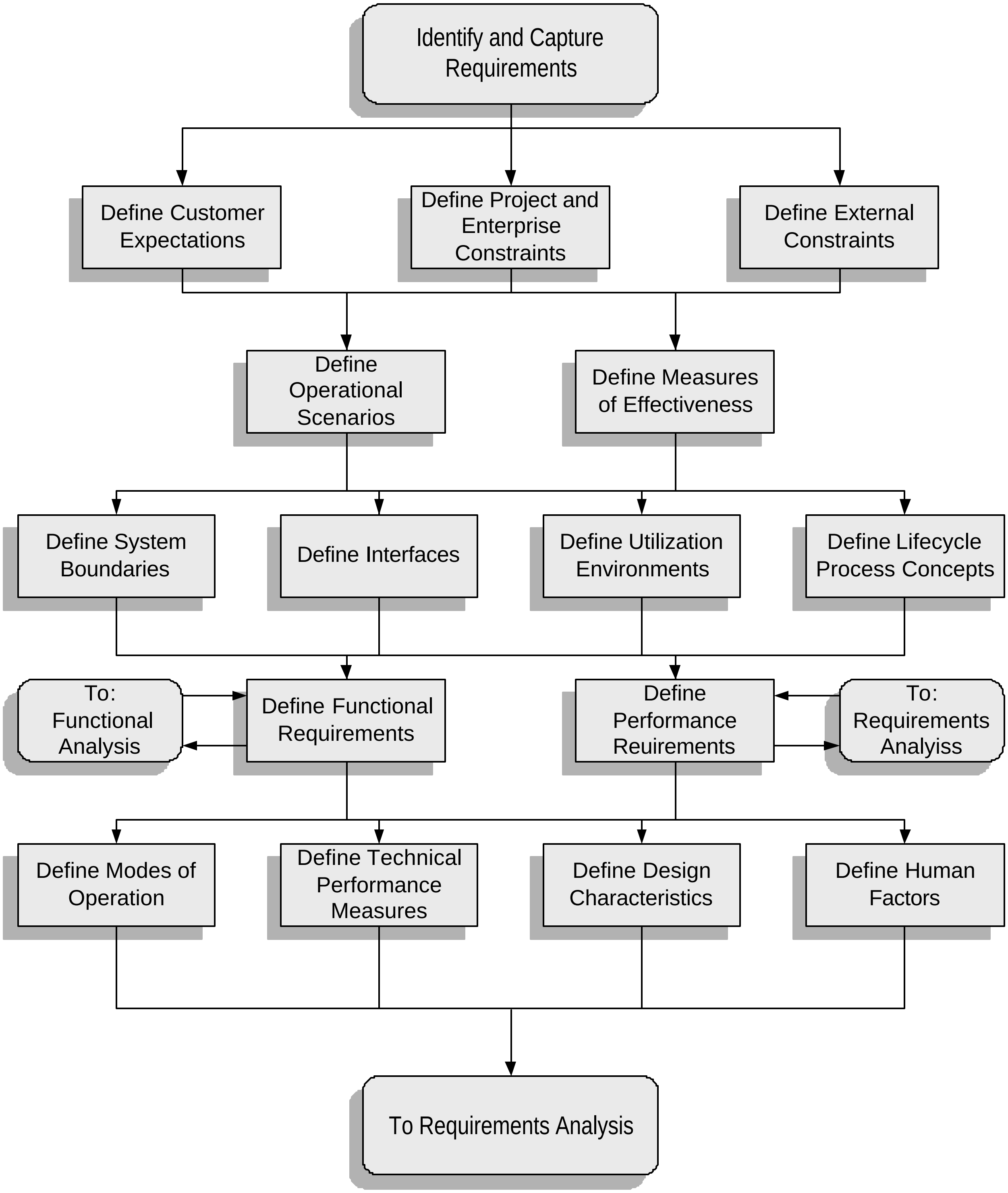

Figure 4.3-4. Identify and Capture Requirements Flow

4.3.3.1.3.3 Step 1.3: Define External Constraints

External constraints that impact design solutions or implementation of SE activities are identified and defined. These include:

- U.S. Government and international laws and regulations
- Industry, international, and other general specifications, standards, and guidelines
- ICAO SARPs
- RTCA MOPS and MASPS
- Human-related specifications, standards, and guidelines
- The technology base
- Interfacing systems

4.3.3.1.3.4 Step 1.4: Define Operational Scenarios

Operational scenarios that define the range of the anticipated system uses are identified and defined. For each operational scenario, expected interactions with the environment and other systems, human tasks and task sequences, and physical interconnections with interfacing systems and platforms are defined.

Data for this step comes from the CONOPS, pPRs and fPRs, and the NAS Architecture.

4.3.3.1.3.5 Step 1.5: Define Measures of Effectiveness

System effectiveness measures that reflect overall stakeholder needs and operational suitability are defined. Measures of Effectiveness (MOE) are measures of operational effectiveness and suitability in terms of operational outcomes. They identify the most critical performance requirements to meet system-level mission objectives and will reflect key operational needs in the operational requirements document.

Key MOEs may include performance, safety, operability, usability, reliability, maintainability, time and cost to train, workload, human performance requirements, or other factors.

Data for this step comes from the CONOPS, pPRs and fPRs, the NAS Enterprise Architecture, the NAS Level Requirements, and operational scenarios.

4.3.3.1.3.6 Step 1.6: Define System Boundaries

System boundaries are defined as follows:

- System elements that are under design control and elements that are not
- Expected interactions among system elements under design control and external and/or higher level and interacting systems outside the system boundary

Data for this step comes from any internal, external, policy, or technology constraints; CONOPS; SLMN; pPRs and fPRs; and Functional Analysis.

4.3.3.1.3.7 Step 1.7: Define Interfaces

The functional and physical interfaces are defined to external or higher level and interacting systems, platforms, and/or products in quantitative terms. Functional and physical interfaces may include mechanical, electrical, thermal, data, communication, procedural, human-machine, and other interactions required. Interfaces may also be considered from an internal/external perspective. Internal interfaces address elements inside the boundaries established for the system; they are generally identified and controlled by the contractor responsible for developing the system. External interfaces involve entity relationships outside the established system boundaries.

Data for this step is in IRDs, ICDs, Functional Analysis, SLMN, and pPRs and fPRs.

4.3.3.1.3.8 Step 1.8: Define Utilization Environments

Utilization environments for each of the operational scenarios are defined. All environmental factors—operational and ambient—that may impact system performance are identified and defined. Also identified are factors that ensure that the system minimizes the potential for human or machine errors or for failures that cause accidents or death and that impart minimal risk of death, injury, or acute chronic illness, disability, and/or reduced job performance of the humans who support the system lifecycle. Specifically, weather conditions (e.g., rain, snow, sun, wind, ice, dust, and fog); temperature ranges; topologies (e.g., ocean, mountains, deserts, plains, and vegetation); biological factors (e.g., animal, insects, birds, and fungi); time (e.g., day, night, and dusk); induced factors (e.g., vibration, electromagnetic, acoustic, x-ray, and chemical); or other environmental factors are defined for possible locations and conditions conducive to system operation. It is recommended that effects on hardware, software, and humans be assessed for impact on system performance and lifecycle processes.

Data for this step may be contained in the OSED, Trade Studies, Specialty Engineering analysis, and FAA and military standards, specifications, and handbooks. References to many of these sources appear in Appendix G.

4.3.3.1.3.9 Step 1.9: Define Lifecycle Process Concepts

The outputs of steps 1.1 through 1.8 are analyzed to define lifecycle process requirements needed to develop, produce, test, distribute, operate, support, train, and dispose of system products being procured. These requirements are:

- **Manpower**. The required job tasks and associated workload used to determine the number and mix of humans who support the system lifecycle processes are identified and defined.

- **Personnel**. The experiences, aptitudes, knowledge, skills, and abilities required to perform the job tasks that are associated with the humans who support the system lifecycle are identified and defined.

- **Training**. The instruction education and on-the-job or team training necessary to provide humans and teams with knowledge and job skills needed to support the system lifecycle processes at the specified levels of performance are identified and developed.

- **Human Engineering**. Human cognitive, physical, and sensory characteristics that directly contribute to or constrain lifecycle system performance and that impact human-machine interfaces are identified.

- **Safety**. The System Safety Engineering analysis derives and identifies requirements that are designed to control the risk of identified safety hazards.

4.3.3.1.3.10 Step 1.10: Define Functional Requirements

Functional requirements for each function of the system as determined by the Functional Analysis process (Section 4.4) are defined, describing what the system will do. The functions identified are used in subsection 4.3.3.1.3.11 to define how well the functions shall be performed and to establish the performance requirements. All system requirements involve both functional and performance aspects that ensure that requirements are complete, consistent, and verifiable.

4.3.3.1.3.11 Step 1.11: Define Performance Requirements

Performance requirements for each system function are defined. Performance requirements describe how well functional requirements are performed to satisfy the MOEs. These performance requirements are MOPs that are allocated to subfunctions during functional decomposition analysis and that are the criteria against which design solutions (derived from Synthesis (Section 4.5)) are measured. MOPs quantify a technical or performance requirement directly derived from the MOEs. MOPs also reflect key performance requirements in the system specification. MOPs are directly traceable to the MOEs and are used to derive, develop, support, and document the performance requirements that will be the basis for design activities and process development.

There are typically several MOPs for each MOE, which bound the acceptable performance envelope.

4.3.3.1.3.12 Step 1.12: Define Modes of Operation

The system modes of operation (e.g., full system, emergency, training, and maintenance) are defined for the system being procured. The conditions (e.g., environmental, configuration, and operation) that determine the modes of operation are defined.

Data for this step may come from the NAS or system-level CONOPS, SLMN, OSED, operational scenarios, or Functional Analysis.

4.3.3.1.3.13 Step 1.13: Define Technical Performance Measures

Technical Performance Measures (TPM) are defined that describe the key indicators of system performance. TPMs are derived directly from the MOPs and are selected because they are critical for controlling and periodically reviewing performance. TPMs help assess design progress, assess compliance to requirements throughout the WBS, and assist in monitoring and tracking technical risk. They can identify the need for deficiency recovery and provide information to support cost-performance sensitivity assessments. Examples of TPMs include range, accuracy, weight, size, availability, power output, power required, process time, and other product characteristics that relate directly to the system operational requirements.

It is recommended that selection of TPMs be limited to critical MOPs that, if not met, put the project at cost, schedule, or performance risk. Specific TPM activities are integrated into the System Engineering Master Schedule to periodically determine achievement to date and to measure progress against a planned value profile.

Data for this step comes from the CONOPS or the SLMN.

4.3.3.1.3.14 Step 1.14: Define Design Characteristics

Required design characteristics that are required to achieve operational suitability (e.g., color, texture, size, anthropometrical limitations, weight, and buoyancy) are identified and defined for the system being procured. Design characteristics that are constraints and that may be changed based on tradeoff analysis (Synthesis (Section 4.5)) are identified.

Data for this step comes from the CONOPS, SLMN, OSED, Functional Analysis, Tradeoff Studies, and FAA and military standards, specifications, and handbooks.

4.3.3.1.3.15 Step 1.15: Define Human Factors

Human factor considerations (e.g., design space limits, climatic limits, eye movement, reach ergonomics, cognitive limits, and usability) are identified and defined that affect operation of the system being procured. Human factors that are constraints and may be changed based on tradeoff analysis are identified.

Data for this step comes from the CONOPS, SLMN, OSED, Functional Analysis, Tradeoff Studies, Specialty Engineering analysis, and FAA and military standards, specifications, and handbooks.

4.3.3.2 Step 2: Analyze and Decompose Requirements

This activity translates the functional architecture developed in Functional Analysis (Section 4.4) into Primitive Requirement Statements (PRS) that, in turn, are translated into Mature Requirement Statements (MRS).

4.3.3.2.1 Analyze Requirements

The functional architecture is the primary input to the Requirements Management process. A functional architecture describes "what" a system will accomplish. The functional architecture consists of functional flow block diagrams (FFBD), timeline sequence diagrams, and functional N-squared (N^2) charts described in Functional Analysis (Section 4.4). The functional architecture is a living document that increases in level of detail along with the decomposition of requirements. It is recommended that there be a level of functional analysis and corresponding functional architecture for every level of requirements (Table 4.3-1). The Requirements Management process uses the Functional Architecture to derive PRSs.

The Requirements Management process starts with recognition of a need or shortfall in system capability and progresses in increasing detail, as shown in Table 4.3-1.

Table 4.3-1. Functional Architecture to Requirements Traceability Hierarchy

Functional Architecture	Requirements
CONOPS →	Service Level Mission Need
Functional Analysis 1 →	Preliminary Program Requirements
Functional Analysis 2 →	Final Program Requirements
Functional Analysis 3 →	System Level Specification
Functional Analysis N →	System Specification to N level

4.3.3.2.1.1 Function to Requirements Transformation

Function transformation transforms functions into the functional and performance PRSs that describe the system attributes that achieve customers' needs.

A functional architecture (from Functional Analysis (Section 4.4)) is transformed into PRSs through two fundamental methods: (1) a structured analysis methodology called System Functional Requirements Analysis (SFRA) and (2) Functional Architecture Referencing (FAR).

Regardless of the method used, the result is a set of PRSs associated with the system functions.

4.3.3.2.1.1.1 System Functional Requirements Analysis

SFRA is a structured methodology for developing requirements from a functional architecture. It requires building a matrix of functions and system characteristics then assigning a PRS to each function/characteristic pair if one is needed. The following steps produce a list of functions for which PRSs are developed.

4.3.3.2.1.1.1.1 List Functions

From the functional architecture, the functions are listed on the vertical axis of a table, such as the example in Table 4.3-2. A tree diagram may be used to assist in creating the function list.

Table 4.3-2. System Characteristic Matrix

Functions	Characteristics	Performance		Specialty Engineering				Environment		
		Accuracy	Thermal	Reliability	Safety	Spectrum	Operator workload	Radiation	Lightning	Precipitation
Detect AC state vector	Determine aircraft (AC) horizontal location	2	1		3	N	N	N	N	N
	Determine aircraft vertical location	N	N		N	N	N	N	N	N
	Determine aircraft velocity vector	N	N		N		N			
Transmit voice RF	Convert sound to high frequency signal	N	N	N		N	N	N	N	N
	Convert signal to Electromagnetic (EM) wave	N	N	N	N	N		N		N
	Propagate wave through space-time					N		N	N	N
Distribute NOTAM	Encode Notice to Airmen (NOTAM)	N	N		N		N			
	Determine scope	N	N		N		N			
	Transmit NOTAM	N	N		N	N	N	N	N	N

Note: N = PRS number for the specific intersection.

4.3.3.2.1.1.1.1.1 Tree Diagrams

A tree diagram is constructed from the top down. Each subfunction is shown as a branch of the tree. Using the FFBD in Figure 4.4-23 (see Functional Analysis, Section 4.4) as an example, the tree diagram in Figure 4.3-5 was developed as an incomplete example of what the tree diagram might look like. A completed diagram might result in a family tree hierarchy of functions.

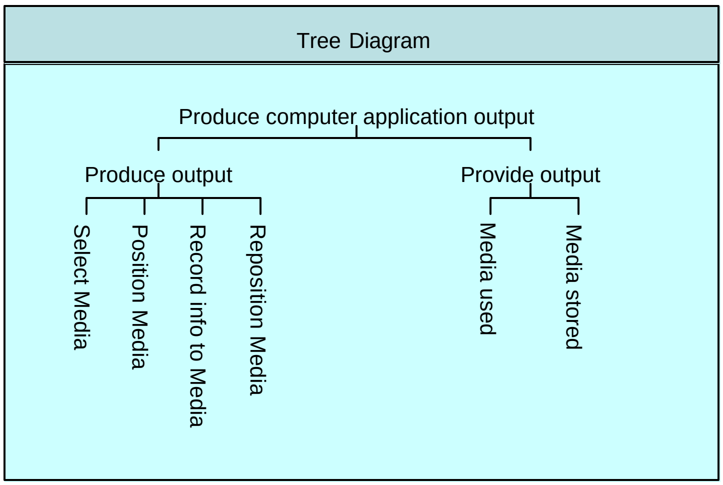

Figure 4.3-5. Tree Diagram Example

4.3.3.2.1.1.1.2 List System Characteristics

System characteristics are developed by identifying all measurable product characteristics perceived as related to meeting customer requirements. These characteristics come from (1) the external inputs described in subsection 4.3.2.1 and (2) analyses conducted in Specialty Engineering (Section 4.8). The characteristics include specialty requirements, constraints, standards, handbooks, management decisions, policies, and legacy requirements. The system characteristics are listed on the horizontal axis of Table 4.3-2. The specific categories and characteristics are unique to and change with each system. The material shown is for illustration only.

4.3.3.2.1.1.1.3 Determine Intersections

This step determines if a need exists to translate a particular function into a PRS. If there is a significant relationship between the function and the characteristic, a PRS number is placed in that cell. "Significant" means that it was determined, using engineering judgment, that the function shall have one or more of the related characteristics in order to meet the customer's need. Wherever there is a number, a unique PRS is required to describe that relationship. The number is associated with the unique PRS that describes the function-characteristic combination. If, this combination is not significant or nonexistent, then a PRS is **not** written for that intersection.

4.3.3.2.1.1.1.4 Develop Primitive Requirements Statements

A PRS for each intersection in the table is developed in accordance with the procedure in subsection 4.3.3.2.1.1.3.

4.3.3.2.1.1.2 Functional Architecture Reference

This method generates PRSs from the standards, handbooks, and Specialty Engineering analyses. The functional PRSs are developed by referencing the functional architecture. Because of the risk of missing critical requirements, it is recommended that this method be used only when there is not enough time to perform an SFRA.

4.3.3.2.1.1.2.1 Derive Primitive Requirements Statement From Standard Sources

A list of PRSs is developed. The PRSs are derived by using the sources described in Specialty Engineering (Section 4.8) and the inputs listed in subsection 4.3.3. The PRSs are developed in accordance with subsection 4.3.3.2.1.2 below.

For example, assume that a reliability analysis derived a requirement that states: "Transmitter Mean Time Between Failures (MTBF) greater than 5,000 op hours." The PRS is listed as a requirement in this list. Table 4.3-3 provides an example.

Table 4.3-3. Primitive Requirement Statements List

PRS Number	Primitive Requirement Statement	Functional Reference
Assign a unique number to the PRS	This is the derived PRS	Assign the PRS to a function in the functional architecture
126	Transmitter MTBF greater than 5,000 operating hours	F.3.2.1.1

4.3.3.2.1.1.2.2 Relate Primitive Requirements Statement to Functional Architecture

The functional architecture and existing PRSs are reviewed, and each PRS is assigned to a function in the functional architecture. Each requirement is assigned to a function, and it is recommended that each function have one or more requirements assigned to it.

4.3.3.2.1.1.2.3 Sort the Primitive Requirements Statements by Functional Reference

The list of PRSs developed in subsection 4.3.3.2.1.1.2.2 is sorted or grouped so that requirements allocated to an individual function are together. Table 4.3-4 is an example.

Table 4.3-4. Primitive Requirement Statements List

PRS Number	Primitive Requirement Statement	Functional Reference
126	Transmitter MTBF greater than 5,000 op hours	F.3.2.1.1
34	Transmitter EMI hardened greater than 50,000 volt-meters	F.3.2.1.1
212	Transmitter power less than 10 watts	F.3.2.1.2
6	Transmitted power less than or equal to table 4.3 in HERP standard 6	F.3.2.1.2

PRS Number	Primitive Requirement Statement	Functional Reference
57	Transmitted power less than or equal to table 2.1 in HERF standard 4.4	F.3.2.1.2

Note: EMI= electromagnetic interference; HERP= Hazard of Electromagnetic to Personnel; HERF= Hazard of Electromagnetic Radiation to Fuels

4.3.3.2.1.1.2.4 Write the Functional Primitive Requirements Statement

Once requirements are sorted to functions, the functional PRSs are derived. First, the functional architecture used is appended to the requirements document. Then, for each group of PRSs, a functional PRS is defined in the following manner:

> **[Element] functions + as defined in + [Functional Reference (include page and figure number)]**

For the above example table, two functional PRSs are added as shown in Table 4.3-5.

Table 4.3-5. Grouped and Sorted Primitive Requirement Statements List

PRS Number	Primitive Requirement Statement	Functional Reference
126	Transmitter MTBF greater than 5,000 op hours	F.3.2.1.1
34	Transmitter EMI hardened greater than 50,000 volt-meters	F.3.2.1.1
220	Transmitter functions as defined in F.3.2.1.1, page A-26, figure A.2.2	F.3.2.1.1
212	Transmitter power less than 10 watts	F.3.2.1.2
6	Transmitted power less than or equal to table 4.3 in HERP standard 6	F.3.2.1.2
57	Transmitted power less than or equal to table 2.1 in HERF standard 4.4	F.3.2.1.2
221	Transmitter functions as defined in F.3.2.1.2, page A-28, figure A.2.4	F.3.2.1.2

4.3.3.2.1.1.3 Develop Mature Requirements Statements

Once the list of PRSs is developed using either SFRA or FAR, the PRSs are transformed to MRSs in accordance with subsection 4.3.3.2.1.3.

4.3.3.2.1.2 Primitive Requirements Statements

Requirements are first captured as a list of PRSs. A PRS is ***a primitive form of a requirement statement that has no punctuation or formal sentence structure and is not written in a formal specification style.*** The PRS form is used at this stage to improve the early requirements identification capability by removing the rigor of writing MRSs from the early concept development and to remove the considerable cost of forming mature requirements. Each PRS is uniquely numbered and follows a simple three-part format:

Name + Relation + Value

The name describes the characteristic or attribute to control; the relation details the connection between the attribute and its control value; and the value sets a quantifiable number with units or defines a standard. Numerical requirements use one of six possible relations: less than, greater than, equal to, less than or equal to, greater than or equal to, or between a range of values. For non-numerical requirements, words such as "is," "be," and "conforms to" are used as the relation. Table 4.3-6 provides several examples of a PRS.

Table 4.3-6. PRS Examples

Name	Relation	Value	Units
Item Weight	less than or equal to	5120	Kilograms
Item reliability	greater than or equal to	.998	(none)
Item power output	greater than or equal to	100	Megawatts
Item memory margin	greater than or equal to	100	Percent
Item high turn rate	equal to	90	Degree/min
Item screen refresh rate	equal to	20	Frame/sec
Item input power	in accordance with	FAA-G-2100h	(none)

4.3.3.2.1.3 Mature Requirements Statement

Once the PRSs at any level are identified, they are synthesized into MRSs that satisfy the characteristics and attributes of good requirements. An MRS is ***a written statement of a requirement in one or more complete sentences in a familiar language (normally English) using the idiom of a particular business sector, such as air traffic control or avionics***.

Requirements characteristics are the principal properties of the MRS (see subsection 4.3.3.2.1.4). Characteristics may apply to individual requirements or to aggregated requirements. A well-defined set of MRSs needs to exhibit certain individual and aggregate characteristics (as described in subsection 4.3.3.2.1.4). Well-defined requirements are clear, concise, and simple. This activity describes (1) how to build requirements from PRSs and (2) the essential characteristics of well-defined requirements.

The result of performing this activity is a baseline set of requirements that satisfies all of the characteristics described herein and that is recorded and maintained over the lifecycle of the product; the set of requirements is also accessible to all parties.

Each PRS is converted to an MRS in the form of specification text. A specification for a system is a published set of requirements that has been properly refined and formatted into more precise language than used for the PRSs. Usually, each PRS becomes a short paragraph when converted into specification text.

Normal specification standards require that the content of a requirements document include complete sentences organized in a particular way. Each requirement statement shall (1) be written in proper grammar, (2) make appropriate use of standard constructs, (3) possess the characteristics and attributes of good requirements, and (4) comply with a specified standard format.

A PRS is converted into an MRS in specification text by adding the characteristics described in the following paragraphs.

- **Paragraph Number.** The type of requirements is identified and a paragraph number is assigned according to the required format. The numbering format is in accordance with the Federal Aviation Administration Acquisition System Toolset (FAST) template or FAA-STD-005 or MIL-STD-961.
- **Paragraph Title.** A paragraph title is identified that is linked to the named or controlled PRS attribute**.**
- **Subject.** The subject of the requirements is the main topic of the sentence and is linked to the named or controlled PRS attribute.
- **Directive Verb.** The directive verb in the requirement sentence directs the action required and relates the named or controlled attribute to the value. See subsection 4.3.3.2.1.3.1.1 below.
- **Sentence Ending.** The requirements sentence ends with a period and with a commonly used word or phrase that provides a reference to a standard or specification. See subsection 4.3.3.2.1.3.1.2 below.
- **Explanatory Information.** Explanatory, defining, or clarifying information is added after the requirements sentence if necessary to ensure understanding and avoid ambiguity. Explanatory information is often best contained in a glossary; however, if this information is needed, the requirement may not be well formed.

4.3.3.2.1.3.1 Standard Constructs

Standard constructs are used to record requirements to ensure that they have good requirements characteristics.

4.3.3.2.1.3.1.1 Directive Verbs

All requirements documents have directive verbs that denote action, as follows:

- Use the verb “shall” to denote compulsory or mandatory requirement or action that the person being directed is obliged to take. (For example: “The system weight shall be less than 1000 pounds”; or “The contractor shall furnish all facilities and equipment necessary for the tests specified herein.”)
- Use the verb “may” to denote permission or an option that is not obligatory. (For example: “For instruction books of 50 pages or less, multi-ring binding may be employed in lieu of saddle stitching.”)
- Use the verb “will” to denote a declaration of purpose on the part of the government. (For example: “The Contracting Officer will furnish shipping instructions upon request.”)

- The verb “should” is not used in requirements documents. Although the word “should” is used to denote action that is recommended but not obligatory, it may imply duty or obligation in legal usage.

4.3.3.2.1.3.1.2 Commonly Used Words and Phrasings

Certain words and phrases are frequently used in requirements documents. The following rules shall apply:

- Referenced documents requirements are to be written as follows:
  - “ …in accordance with Specification (or Standard)…”
  - “…shall be as specified in Specification (or Standard)…”
  - “…shall conform to…
  - “…conforming to Specification (or Standard)…”
- The phase “unless otherwise specified” is used to indicate an alternate course of action. The phrase comes at the beginning of the sentence and, if possible, at the beginning of the paragraph. This phrase is limited in its application and used sparingly.
- The term “and/or” shall not be used in requirements documents. The following example conveys the desired meaning: “The panel shall be supported on brackets, pillars, or both.”
- Do not use “minimum” and “maximum” to state limits. Use “no less than” or “no greater than.” This standard construct avoids the ambiguity associated with the limiting values. This does not mean that the words “minimum” and “maximum” may not be used at all, just not to state limits.

4.3.3.2.1.3.1.3 Words and Phrases To Avoid

It is recommended that specific words and phases be avoided because they are vague, ambiguous, and general. They include “flexible,” “fault tolerant,” “high fidelity,” “adaptable,” “rapid” or “fast,” “adequate,” “user-friendly,” “support,” “maximize,” “minimize,” and “shall have the capability to.”

4.3.3.2.1.4 Characteristics of Individual Requirements

Characteristics of individual requirements may be used for requirements development as well as in requirements reviews and audits for assessing the quality of requirements. Descriptions of these characteristics follow (with synonyms in parenthesis).

4.3.3.2.1.4.1 Necessary

The stated requirement is an essential capability, characteristic, or quality factor of the product or process. If removed or deleted, it may cause a deficiency that cannot be remedied by other capabilities of the product or process.

This is a primary characteristic that makes a well-defined requirement. Specifications with unnecessary requirements add cost to the product. If a necessary requirement is deleted from the specification, a major need may not be met, even if all other requirements are satisfied.

A good test of necessity is whether the requirement can be traced to higher level documentation. In the case of a system specification, traceability may be verified to user documentation, such as the CONOPS. If there is no parent requirement, the requirement may not be necessary.

4.3.3.2.1.4.2 Concise (Minimal, Understandable)

The requirements statement includes only one requirement that simply and clearly states only what shall be done, making it is easy to read and understand. To be concise, the requirements statement does not contain any explanations, rationale, definitions, or descriptions of system use, which are used in text analysis and trade study reports, operational concept documents, user manuals, or glossaries. A link may be maintained between the requirements text and the supporting analyses and trade studies in a requirements database so that the rationale and explanations may be referenced.

Determining what constitutes one requirement is a constant struggle in developing requirements and often requires engineering judgment. An example is the requirement in FAA automation systems for a Minimum Safe Altitude Warning/Conflict Alert alarm. This alarm requires an aural alarm and a visual alarm to warn the controller about potential unsafe conditions. Therefore, the question is: Is this one requirement, or does a requirement need to be written for each condition? Multiple requirements in one paragraph are undesirable. Each requirement needs to be managed and verified, and, as such, has an associated cost.

One decision-making approach is to determine how the requirement is to be verified. In the alarm example, it is recommended to verify that the alarms work together; therefore, any test to verify the alarms shall include both the aural and visual alarms, thus combining the aural and visual alarms into one requirement.

4.3.3.2.1.4.3 Implementation-Free (Solution Neutral)

The requirement states what is required, not how the requirement needs to be met. The requirement states the desired result in functional and performance terms, not in terms of a solution set. It is also recommended that a requirements statement not reflect a design or implementation nor describe an operation, although interface requirements are generally an exception to this rule.

This characteristic of a requirement is perhaps the hardest to judge and implement. At the system level, requirements may be truly abstract or implementation-free. The system requirements have to be synthesized by a system design solution. After a trade study has been conducted between alternatives and a candidate solution has been selected, the system requirements have to be allocated to the elements defined by the system design. This incremental procedure of allocating requirements to the next lower level elements, which depends on system design, means that one level of design is the requirement at the next lower level. The conclusion is that a requirement is implementation-free at the level that it is being specified, but is a result of the design activity at the level above it.

Interface requirements are usually an exception to the implementation-free rule. Interface requirements are specified in IRDs that describe a specific design or an interface or mating part. The interface requirement shall provide complete information so that the two sides of the interface may be designed to work as specified when connected to each other.

4.3.3.2.1.4.4 Attainable (Achievable or Feasible)

The stated requirement may be achieved by one or more developed system concepts at a definable cost. This implies that a high-level conceptual design has been completed or research and development and cost tradeoff studies have been conducted.

This characteristic is a test of practicality of the numerical value or values set forth in a requirement. It signifies that adequate analyses, studies, and trades have been performed to show that the requirement may be satisfied by one or more concepts and that the technology cost associated with the concept(s) are reasonable within program cost constraints.

4.3.3.2.1.4.5 Complete (Standalone)

The stated requirement is complete and does not need further amplification and provides sufficient capability.

This characteristic specifies that each requirement be stated simply using complete sentences. It is recommended that each paragraph state everything required on the topic and that the requirement be capable of standing alone when separated from other requirements.

4.3.3.2.1.4.6 Consistent

The stated requirement does not contradict other requirements and does not duplicate another requirement. The same term is used for the same item in all requirements.

This characteristic of well-defined requirements is usually well understood and does not cause much discussion. However, in a large set of requirements that are not well organized by some clearly defined categories, it may be hard to spot duplications and inconsistencies. Therefore, organizing requirements in accordance with a standard or template is important so that inconsistencies may be identified. It is also important to maintain a glossary of program terms because the meaning of some words is domain dependent.

4.3.3.2.1.4.7 Traceable

It is recommended that each stated requirement be developed in a way that allows it to be traced back to its source. A requirement also needs to identify related requirements (i.e., parents, children, peers) and requirements that might be impacted by changes to it.

This characteristic contributes to completeness by verifying that all requirements have a source or are allocated. It also helps to eliminate unnecessary or missing requirements.

4.3.3.2.1.4.8 Unambiguous

Each requirement shall have **one** interpretation. Language used in the statement shall leave no doubt as to the intended descriptive or numeric value.

This characteristic is difficult to achieve because the language may be unstructured and, in some cases, the same sentence may mean different things to different people. It is helpful to use standard specification language constructs and commonly used words and phases and to avoid using the constructs cited in subsection 4.3.3.2.1.3.1.3 above.

4.3.3.2.1.4.9 Verifiable (Testable)

Each requirement shall have an identified means by which to verify that it meets the characteristics established above. The stated requirement is not vague or general but is quantified in a manner that may be verified by one of the verification methods described in Validation and Verification (Section 4.12).

The characteristic of verifiability needs to be considered at the same time that a requirement is being defined. A requirement that is not verifiable is a problem because it involves acceptability of the system. To be verifiable, a requirement shall be stated in measurable terms.

4.3.3.2.1.4.10 Allocatable

All stated requirements are allocated to the lowest level possible within the physical architecture or assigned to an organization.

This characteristic is important because it helps to eliminate requirements that are not complete, concise, clear, and necessary. If a requirement is not allocatable to the physical architecture, it is probably not a well-formed requirement.

4.3.3.2.1.5 Characteristics of Aggregate Requirements

Aggregate requirements are a set of requirements for a system or element that specifies its characteristics in totality. Usually, this requirement set is in requirements documents, specifications, or statements of work (SOW). Characteristics of an aggregate requirements set is identical to those of individual requirements, with the addition of the following:

4.3.3.2.1.5.1 Complete

The set of requirements is complete and does not need further amplification. The set of requirements has addressed all categories (subsection 4.3.3.2.1.6.3) of requirements and covers all allocations from higher levels.

This characteristic addresses the difficulty of identifying requirements that are necessary but are missing from the requirements set. One approach to identify missing requirements is to walk through the Operational Concept and its associated scenarios from start to finish, then walk through the same set of scenarios and ask "what if" questions. This approach usually uncovers a new set of requirements. A second approach is to develop a checklist of topics or areas, such as a specification outline, and verify that requirements exist in each topic area; or, if they do not exist, that there is a good reason for it. A third approach is to check the aggregate requirements set against a higher level document (if one exists) to verify that all allocated requirements have been included in the set.

4.3.3.2.1.5.2 Consistent

The set of requirements has no individual requirements that are contradictory. Requirements are not duplicated, and the same term is used for the same item in all requirements.

This characteristic addresses the problem of identifying unnecessary or conflicting requirements that are inadvertently included in the set. Assigning program-unique identification to each requirement and conducting thorough reviews are ways to eliminate these requirements.

4.3.3.2.1.6 Additional Requirements Properties

The following subsections describe secondary properties of individual requirements that provide supplementary information about the requirement and its relationship to other requirements and source documents. However, these properties are not essential in all cases. They are typically used in a requirements management database to provide attributes for sorting, classifying, tracing, and managing individual requirements.

4.3.3.2.1.6.1 Requirement Identification

Each requirement is assigned a program-unique identifier (PUI) for identification and tracking purposes. The PUI may be either numeric or alphanumeric and assigned automatically if a requirements management tool is used. The requirement identifier assists in identifying the requirement, maintaining change history, and providing traceability.

4.3.3.2.1.6.2 Level

This property indicates the level at which the specific requirement is applicable in the system hierarchy or WBS. A level I requirement may indicate a top- or system-level requirement; a level II requirement may be a segment or component-level requirement.

4.3.3.2.1.6.3 Requirements Category

Requirements fall into two categories—nonproduct and technical.

4.3.3.2.1.6.3.1 Nonproduct Requirements

Nonproduct requirements are different from technical requirements: They are not imposed on the system or product to be delivered but on the process to be followed by the program. They are usually task oriented. Nonproduct requirements are managed similarly to technical requirements and need to be necessary, concise, attainable, complete, consistent, and unambiguous in the same manner as technical requirements. Nonproduct requirements are often referred to by industry as “Program Requirements.”

Nonproduct requirements are stakeholder or user requirements imposed through contractual vehicles other than specifications, including the contract or contract SOW. Nonproduct requirements include:

- Compliance with Federal, State, or local laws, including environmental laws
- Administrative requirements (e.g., security); stakeholder/vendor relationship requirements (e.g., directives to use government facilities for specific types of work such as tests); and specific work directives (e.g., directives included in the SOW and Contract Data Requirements List (CDRL))

Nonproduct requirements may also be imposed on a program by agency policy, directives, or practice.

4.3.3.2.1.6.3.2 Technical Requirements

Technical requirements apply to the system or service being procured. Technical requirements are described in requirement documents, system specifications, and interface documentation. The types of technical requirements include:

- **Operational Requirements**. These requirements define the interfaces between the end-user and each functional system, maintenance concept and each system, and various other support and related functions or equipment.
- **Functional Requirements**. These requirements identify what the system must do, and not how well the system accomplishes it. They are based on Functional Analysis (Section 4.4).
- **Performance Requirements**. These requirements define how well the product performs its intended function (e.g., accuracy, fidelity, range, resolution, and response times).
- **Interface Requirements**. These requirements identify the performance, physical, and functional requirements associated with the product interfaces (boundary conditions). Interface development is described in Interface Management (Section 4.7).
- **Constraint Requirements**. These requirements identify limitations or restrictions that bound the solution set and may mature into derived requirements. Following are typical constraint requirements.
- **Regulatory Requirements**. These requirements are imposed by statutes or regulations (e.g., the AMS, FAA regulations or directives, Occupational Safety and Health Administration (OSHA) regulations, and Environmental Protection Agency (EPA) directives).
- **Reliability, Maintainability, and Availability/Supportability**. These requirements identify the user's system readiness and mission performance requirements, physical environments, and resources (e.g., personnel, training, and facilities) available to support the mission. Supportability requirements are based on the maintenance concept.
- **Safety Requirements**. These requirements are defined to control the effects of failure conditions, hazards, and/or safety-related functions.
- **Health Hazard Requirements**. These requirements are defined to control the effects of failure conditions, hazards, and health-related functions.
- **Human Performance Interface Requirements**. These requirements define the human system interface(s).
- **Producibility Requirements**. These requirements define the producibility of a product that involves identifying materials, special tools, test equipment, facilities, personnel, and procedures. They identify the manufacturing technology needs, availability of critical materials, long-lead procurement requirements, and manufacturing test requirements, among other aspects.

4.3.3.2.2 Checklist for Writing and Evaluating Requirements

The following guidelines for writing and evaluating requirements contain representative questions; the list is not intended to be comprehensive.

- **Technical Considerations**
  - Does the requirement state a valid need?
  - Is the requirement verifiable?
  - Has the verification approach been identified?
  - Are the necessary interface requirements stated?
  - Are appropriate data (e.g., tables, figures) included?
  - Are the stated references clearly applicable to the requirement?
  - Is the requirement within the span of knowledge of the requirement owner?
  - Does the requirement have stated values for quantities?
  - Are words that imply a design avoided?
- **Traceability Considerations**
  - Are the applicable parent, child, and peer requirements identified?
  - Are the source and rationale for the existence of the requirement documented?
  - Is the basis for allocation identified?
- **Writing Considerations**
  - Is the requirement stated as a requirement?
  - Is the requirement stated clearly and concisely?
  - Does the requirement represent only one thought?
  - Is the requirement stated positively?
  - Is the requirement void of ambiguous terminology?
  - Is the requirement grammatically correct?
  - Is the requirement punctuated correctly?
  - Is excessive punctuation avoided?

4.3.3.3 Step 3: Derive Requirements

This activity identifies and expresses requirements that result from considering functional analysis, higher level requirements, constraints, or processes. It is recommended that requirements be derived to the lowest practical level before being allocated to the physical architecture or WBS elements to avoid potential reallocation as the requirement set becomes more detailed.

4.3.3.3.1 Identify Derived Requirements

This activity clarifies or amplifies higher level requirements. These derived requirements need to be stated in measurable parameters at increasingly lower levels within the product hierarchy. Derived requirements may result from but are not limited to the following:

- Regulatory policies, program policies, agency practices, and supplier capabilities
- Environmental and safety constraints; the process translates and traces safety-specific system requirements into the software and hardware requirements baseline. Safety program requirements are also reflected in organizational standards and procedures. The process translates and traces safety-specific requirements into the system (hardware and software) baseline. The process assesses system safety program requirement tasks for applicability and incorporation into organizational standards and procedures.
- Architecture choices for performing specific system functions.
- Design decisions
- Hardware-software interfaces not already specified in the baseline interface documentation
- Establishment of detailed requirement values and tolerances (i.e., minimum, maximum, goal, threshold)

Impacts of derived requirements need to be analyzed progressively in all directions (parent, child, and peer) until it is determined that no additional impact is propagated. During this process, the hardware and software architecture design is reviewed for flexibility to adapt to new system requirements.

4.3.3.3.2 Capture Derived Requirements

Derived requirements are captured and treated in a manner consistent with other requirements applicable during the development stage. This activity, like overall SE, is an iterative operation, constantly refining and identifying new requirements as the product concept develops and additional details are defined. As part of the requirements derivation process, areas of the system with volatile requirements are monitored, and requirements specifications are reviewed for ambiguities with the potential of causing software sizing and timing instability and other program impacts.

4.3.3.4 Step 4: Allocate Requirements

This activity allocates or assigns requirements to system, personnel, or support activity components and/or appropriate organizational entities. The allocated requirements consist of all requirements, including the breakdown/decomposition of physical characteristics, functions, reliability/maintainability parameters, and performance parameters. Technical requirements are allocated to the physical architecture defined during the Synthesis process via the Requirements Allocation Matrix (RAM). Nonproduct requirements are allocated to the programmatic process via the WBS. Mapping these requirements identifies the owner that has Responsibility, Authority, and Accountability (RAA) for the respective requirement.

4.3.3.4.1 Allocation Process

This process is applied iteratively when new, changed, or derived requirements are generated. One cycle through the Allocate Requirements process is complete when the currently identified requirements have been accurately allocated to the appropriate system, personnel, or support activity component(s). Subsequent analyses, requirement decomposition, and trade studies may produce additional requirements that define the most balanced requirements allocation for the product.

Typically, the requirements are allocated to components of the system hierarchy defined in the physical architecture provided by the Synthesis process (Section 4.5) or to the program hierarchy defined by the WBS. System requirements (including test and verification requirements) are analyzed, refined, and decomposed to ensure complete functional allocation to system, personnel, or support activity components. When a system-level requirement is allocated to more than one configuration item, the process is used to ensure that the lower level requirements, when taken together, satisfy the system-level requirement. Allocations early in the requirements management process only designate high-level product components, as a complete design may not have been determined. As the product design matures, the identified requirements may be allocated to lower level components in the physical architecture.

As requirements are identified and allocated at different levels of the product hierarchy, the requirements documents may be produced and formatted to fit the need at that particular level. As the requirements and system hierarchy are iteratively defined to lower levels, each requirement ultimately is allocated to the lowest possible level of the system component. The requirements documents below the system level are simply documents containing the requirements that have been allocated to particular product component(s). The RAM documents the results of the allocation process.

4.3.3.4.2 Hardware and Software Allocation

The requirements allocation process allocates requirements to hardware and software configuration items. Allocation may be continued beyond this level depending on program needs. Software, hardware, and interface specifications are analyzed and refined to ensure that all requirements allocated to software and hardware are adequately addressed and that they do not include inappropriate levels of details. Occasionally, requirements are derived from software requirements; these requirements are documented and maintained.

In addition to allocating requirements to system elements, the process may allocate requirements to incremental allocated baselines. The process establishes functional, performance, and verification requirements for each incremental system or software version.

4.3.3.4.3 Requirements Allocation Matrix

The RAM allocates requirements to components of the physical architecture. Figure 4.3-6 is an example of a RAM, which contains the following minimum data:

- The Function ID from the Functional Architecture
- The function Name
- The requirement that was derived from the function
- The component of the physical architecture that will implement the requirement

The RAM may contain additional information about the requirement and allocations, including:

- Date of inclusion or deletion
- Reference WBS number
- Allocated cost estimate
- CDRL item(s) associated with the requirement
- The requirement owner

Requirement Allocation Matrix			
Functional Architecture		Requirement	Physical Architecture
ID	Name		

Figure 4.3-6. Requirement Allocation Matrix

The RAM also establishes and maintains two-way traceability between the design, as depicted in the physical architecture, and the requirements, and between the requirements and the functional architecture. This facilitates the two-way requirements traceability from system specification to hardware and software configuration item specifications.

The RAM will be expanded in the Validation and Verification process to define validation characteristics and to describe Requirements verification methodology (i.e., test, analysis, inspection, demonstration).

A requirements management tool may be used to implement the RAM.

4.3.3.5 Step 5: Establish Verification Methodology

This activity develops a verification approach for each requirement documented in the Validation Table received from Validation and Verification, and the Validation Table is transformed into a VRTM. A Verification Requirement specifies the strategy or method used to verify each requirement, and the VRTM lists the Verification Requirements. The VRTM defines how each requirement is to be verified, the stage in which verification is to occur, and the applicable verification levels. The verification approaches are:

- Inspection
- Analysis
- Demonstration
- Test

A discussion of these methods appears in Validation and Verification (Section 4.12). Figure 4.12-2 is an example of a VRTM. The Test and Evaluation section of the FAST (http://fast.faa.gov/toolsets/index.htm) includes specific guidelines for the VRTM.

4.3.3.6 Step 6: Manage Requirements Changes

This activity manages and controls requirements throughout the product's lifecycle, both before and after instituting formal configuration management, by using a defined change process. The Configuration Management process establishes and maintains requirements baselines both during the requirements analysis process and after formal release of the requirements. The process also identifies and controls all issues and decisions, action items, formal and informal stakeholder/program management desires/directives, and any other real or potential changes to the requirements. This activity is conducted according to the Configuration Management process (Section 4.11).

This change process is invoked when a new requirement is identified or a change occurs during any other activity within the Requirements Management process. The activity is a projectwide, approved approach that documents and controls the identified requirement, its appropriate attributes, its relationship(s) to other requirements, and allocation to the product of functional and/or verification hierarchies. The activity ensures that all involved stakeholders concur with the baselined requirements and any changes. The process controls allocation of requirements between hardware and software.

This process accounts for changes to Government-Furnished Equipment and Contractor-Furnished Equipment safety-critical items that impact development efforts. The process also accounts for changes resulting from the Verification process (Section 4.12). That is, if a test or other form of verification determines that a change in requirements is necessary, the process ensures that the change process is initiated to accomplish that change.

4.3.4 Outputs of Requirements Management

An output of the Requirements Management process is information provided during the process. Outputs are classified as either external or internal according to their destination, as Figure 4.3-7 shows. External outputs are provided to destinations outside SE. Internal outputs are provided to other SE processes described in this manual.

Output requirements are comprehensive and defined for both system products and system processes, including the eight lifecycle functions of development, manufacturing, verification, deployment, operations, support, training, and disposal. Requirements Management is an iterative process that flows from a high level to a low level of requirements (see Figure 4.3-2 above). Therefore, some of the outputs described in the following subsections may be outputs to one stage of the requirements development process and inputs of other stages.

All requirements destinations described are outputs at one point in the process and are captured. The following subsections describe the outputs of the Requirements Management process.

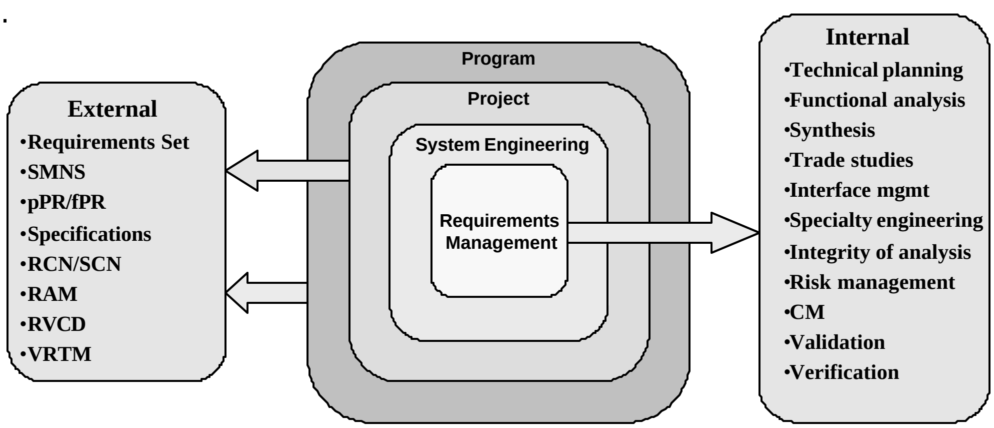

Figure 4.3-7. Output Destinations for Requirements Management

4.3.4.1 External Outputs

Requirements Management provides external outputs to destinations outside SE boundaries.

4.3.4.1.1 Requirements

4.3.4.1.1.1 Requirements Documents

The term “requirements documents” refers to any media that record requirements, either in hardcopy or electronic form. It is a basic rule that all requirements are recorded, including internally generated requirements and those that are generated external to the project. The process does not allow verbal or unwritten requirements.

4.3.4.1.1.1.1 Stakeholder Requirements Documents

Standard requirements documents from an FAA stakeholder include the SLMN, the pPR, and the fPR. Other organizations use the Operational Requirements Document to communicate requirements. Stakeholders convey requirements through memoranda and other media.

4.3.4.1.1.1.2 Specifications

Specifications are a standard form of requirements documents. The technical requirements for a system and its elements are documented through a series of specifications as described in this manual. FAA-STD-005e, “Preparation of Specifications, Standards and Handbooks,” describes the requirements for preparing FAA specifications, standards, and handbooks. MIL-STD-961 is the current standard format for FAA specifications required by FAA-STD-005e. FAA specifications were prepared in the MIL-STD-490 format until MIL-STD-490 was canceled, and some legacy specifications remain in that format. However, MIL-STD-490 specifications may continue to be used for reference. Newly prepared specifications are prepared in accordance with FAA-STD-005e.

4.3.4.1.1.1.2.1 Types of Spécifications

The System Specification (Type A) is the single most important engineering specification document, defining the system allocated baseline and including the results from the needs analysis, feasibility analysis, operational requirements and the maintenance concept, top-level functional analysis, and the critical TPMs. This top-level specification leads to one or more subordinate specifications covering applicable subsystems, configuration items, equipment, software, and other system components. Although the individual specifications for a given program may assume a different set of designations, a generic approach is used here.

4.3.4.1.1.1.2.1.1 System Specification (Type A)

Type A includes the technical, performance, operational, and support characteristics for the system as an entity. It includes allocation of requirements of functional areas, and it defines the various functional-area interfaces. The information derived from the feasibility analysis, operational requirements, maintenance concept, and functional analysis is covered. The Type A specification is the FAA-E-XXXX specification described in FAA-STD-005e.

Type A provides the technical baseline for the system as an entity, is written in performance-related terms, and describes design requirements in terms of “whats,” including the functions that the system is to perform and the associated metrics. It is placed under configuration management at completion of the System Requirements Review.

Type A is the requirements document that FAA uses to procure most systems. It is placed under configuration management before issuance of the system Screening Information Request.

4.3.4.1.1.1.2.1.2 Development Specification (Type B)

Type B includes the technical requirements for any item below the system level where research, design, and development are accomplished. This may cover an equipment item, assembly, computer program, facility, or critical item of support. Each specification includes the performance, effectiveness, and support characteristics that are required in evolving design from the system level down.

A system vendor usually produces the Type B specification in response to the FAA-developed System Specification. It is placed under configuration management at completion of the Preliminary Design Review (PDR).

4.3.4.1.1.1.2.1.3 Product Specification (Type C)

Type C includes the technical requirements for any item below the top system level that is currently in the inventory and may be procured off the shelf. This may cover standard system components (e.g., equipment, assemblies, units, and cables), a specific computer program, a spare part, or a tool. A system vendor usually produces the Product Specification in response to the FAA-developed System Specification or to a vendor-developed Development Specification. It is placed under configuration management at completion of the CDR.

4.3.4.1.1.1.2.1.4 Process Specification (Type D) (Rarely Used in FAA Procurements)

Type D includes the technical requirements that cover a service that is performed on any component of the system (e.g., machining, bending, welding, plating, heat treating, sanding, marking packing, and processing).

A system vendor usually produces the Process Specification in response to the FAA-developed System Specification. The vendor creates it, and the FAA rarely uses it in FAA procurements.

4.3.4.1.1.1.2.1.5 Material Specification (Type E) (Rarely Used in FAA Procurements)

Type E includes the technical requirements that pertain to raw materials, mixtures (e.g., paints, chemical compounds), or semifabricated materials (e.g., electrical cable, piping) that are used in the fabrication of a product.

A system vendor usually produces the Material Specification in response to the FAA-developed System Specification. The vendor creates it, and the FAA rarely uses it in FAA procurements.

4.3.4.1.1.2 Requirements Change Notices

A Specification Change Notice is a formal document specifying that a baselined specification document has been changed.

4.3.4.1.1.3 Requirements Database

Although requirements can come in the hardcopy formats described above, they are always in the original electronic format in automated requirements management tools.

4.3.4.1.1.4 Requirements Verification Compliance Document

The RVCD is output to program and project management for program control activities.

4.3.4.1.1.5 Verification Requirements Traceability Matrix

The VRTM is included as a part of every requirement and specification document. It provides information on the verification and traceability from a requirement to a higher level requirement or to its ultimate source. Validation and Verification (Section 4.12) provides details on this topic.

4.3.4.2 Internal Outputs

The Requirements Management process provides internal outputs to other processes within SE's boundaries and includes outputs to all other SE processes (see Figure 4.3-7 above).

4.3.4.2.1 Integrated Technical Planning

4.3.4.2.1.1 Planning Criteria

Planning criteria describing planned activities for the Requirements Management process are output to the Integrated Technical Planning process (Section 4.2). Appendix E details what is to be included in requirements management planning criteria.

4.3.4.2.1.2 Requirements

The requirements set are an output to the Integrated Technical Planning to use in developing the SEMP and the WBS.

4.3.4.2.2 Functional Analysis

The requirements set at any stage in the requirements development process are an output to the Functional Analysis process (Section 4.4) for developing the next lower level functional analysis.

4.3.4.2.3 Synthesis

4.3.4.2.3.1 Requirements

The requirements set below the SLMN are an output to the Synthesis process (Section 4.5), which allocates requirements to the physical architecture.

4.3.4.2.3.2 RVCD

The Requirements Verification Compliance Document (RVCD) is an output to Synthesis to ensure system compliance through measurable verification requirements.

4.3.4.2.3.3 Requirements Allocation Matrix

The RAM is an output to Synthesis for allocation of requirements to the physical architecture.

4.3.4.2.4 Trade Studies

4.3.4.2.4.1 Requirements

During the Synthesis process, alternative solutions may be proposed that require analysis by conducting trade studies. The Requirements Management process provides requirements for analysis to the Trades Studies process (Section 4.6).

4.3.4.2.4.2 Constraints

Constraints that are developed during the Identify and Capture Requirements step may be used in a trade study and are an output to the Trade Studies process (Section 4.6) in addition to requirements.

4.3.4.2.5 Interface Management

Requirements are provided to the Interface Management process (Section 4.7) at all stages of requirements development so that interfaces are identified and controlled.

4.3.4.2.6 Specialty Engineering

4.3.4.2.6.1 Requirements

To perform Specialty Engineering analyses, the system under study is described. Requirements are a key component of any description, and they are an output to Specialty Engineering (Section 4.8).

4.3.4.2.6.2 RVCD

The RVCD records and provides the verification status of all requirements to Specialty Engineering.

4.3.4.2.7 Integrity of Analysis

4.3.4.2.7.1 Tools/Analysis Requirements

Requirements for tools or analysis that are needed during the Requirements Management process are an output to the Integrity of Analysis process (Section 4.9) so that Analysis Criteria may be developed.

4.3.4.2.7.2 Requirements

Requirements are an output to the Integrity of Analysis process (Section 4.9).

4.3.4.2.8 Risk Management

4.3.4.2.8.1 Concerns and Issues

Concerns and Issues related to accomplishing the mission objectives and satisfying stakeholder needs that are discovered during the Requirements Management process are provided to the Risk Management process (Section 4.10) for review and resolution.

The cumulative status of requirements as a result of previous requirements reviews regarding coverage, balance, mutual conflicts, induced constraints, and so forth are analyzed, and Concerns and Issues are identified.

In performing SE, it is possible that potential requirements management problems may surface as Concerns and Issues, which may take many forms, but, mostly, they may be potential risks to the program.

4.3.4.2.8.2 Requirements

The Requirements Management process identifies requirements to Risk Management (Section 4.10) that are to be analyzed for potential risk. It also produces requirements that are used as mitigations or countermeasures to reduce risk.

4.3.4.2.9 Configuration Management

The Requirements Management process identifies requirements to the Configuration Management process (Section 4.11) that are to be controlled.

4.3.4.2.10 Validation

Requirements developed through the Requirements Management process are to be submitted to the Validation process (Section 4.12) to determine if they are complete, concise, and necessary.

4.3.4.2.11 Verification

4.3.4.2.11.1 Verification Requirements Traceability Matrix

The Requirements Management process expands the Validation Table into a VRTM with assigned verification methods and submits the VRTM to the Verification process (Section 4.12).

4.3.4.2.11.2 Requirements

The Requirements Management process submits requirements to be verified to the Verification process (Section 4.12).

4.3.4.2.12 Lifecycle Engineering

The Requirements Management process submits requirements to Lifecycle Engineering for National Airspace Integrated Logistics System (NAILS) planning to establish objective performance levels for each service element (component) comprising the system at each service or capability delivery milestone.

4.3.5 Requirements Management Process Metrics

Performance of this process is measured and recorded on a regular basis. The following metrics, at minimum, may be used to evaluate process performance:

- Number of changed requirements. This is based on the number of requirements, including both stakeholder-specified and project-derived under active management.
- Unclear, undefined, or ambiguous requirements based on the number of requirements under active management
- Cycle time from requirement change initiation to decision
- Cycle time from change decision to baseline incorporation
- Percent of validated requirements to total proposed requirements

4.3.6 Tools

4.3.6.1 Requirements Tool Characteristics

It is recommended that the database be capable of identifying (i.e., attributes and relationships) and presenting (e.g., internal queries, standard and project-unique reports) the following types of information:

- **Requirements documentation**—statements of the requirements, status, requirement type, rationale, and history (including data configuration control) regarding each requirement, and presenting the requirements in an appropriate user-defined format (e.g., requirement documents, and specifications)
- **Traceability**—linking requirements to their parent, child, and peer requirements, resulting in user-defined requirement traceability matrices
- **Allocation**—linking requirements to the product hierarchy, resulting in user-defined requirements allocation documents
- **Verification**—linking the requirement to specific verification approach attributes, resulting in requirements verification and compliance documents
- **Traceability Impact Assessment**—assessing the impact of proposed changes to the requirement, product, and verification hierarchies
- **Compatibility**—communicating (minimum of import and export capabilities) with other automated tools

4.3.6.2 Requirements Management Software

Deciding whether to use an automated requirements tool for documenting requirements and related information depends on a variety of factors (e.g., size and complexity of the program, number of requirements, budget). There are multiple automated software tools in the marketplace that adequately store and retrieve the requirements and their traceability. A program's tool maintains two-way traceability, from system specifications to hardware and software configuration item specifications. It can be integrated into an overall SE tool suite so that data moves seamlessly between applications.

For small programs, a spreadsheet may be more than adequate to document and control the requirements set. As a program grows and becomes more complex, a tool designed for requirements management may be necessary.

4.3.6.3 Requirements Database

All program personnel have access to the requirements information. Users may have access to either the database itself or to database-derived documentation. A program decision is made concerning the availability and changeability of the requirements data. All personnel may be trained in using the requirements management tool or database, or a select group may manipulate the database and use a distribution media (e.g., intranet Web site or paper) to disseminate the information and collect comments and changes.

4.3.7 References

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