4.1 PERFORM SYSTEM ENGINEERING

4.1.1 Introduction to System Engineering

The Federal Aviation Administration (FAA) System Engineering (SE) method is robust, iterative, and has extensive interdependencies among the SE elements listed in Table 1.2-1 in Chapter 1. The process workflow (see Figure 4.1-1) captures the essence of these linkages and provides a high-level view of the various SE processes and how they functionally interact. These functional interfaces only represent the predominant interaction between each process. The interaction between processes at a lower level is much more involved (i.e., Figure 4.1-1 is a simplified view and does not depict all the ways that processes interact). Figure 3.1-2 (Chapter 3) is an N-squared (N^2) diagram of SE that shows the actual work products exchanged between the various SE processes shown in Figure 4.1-1.

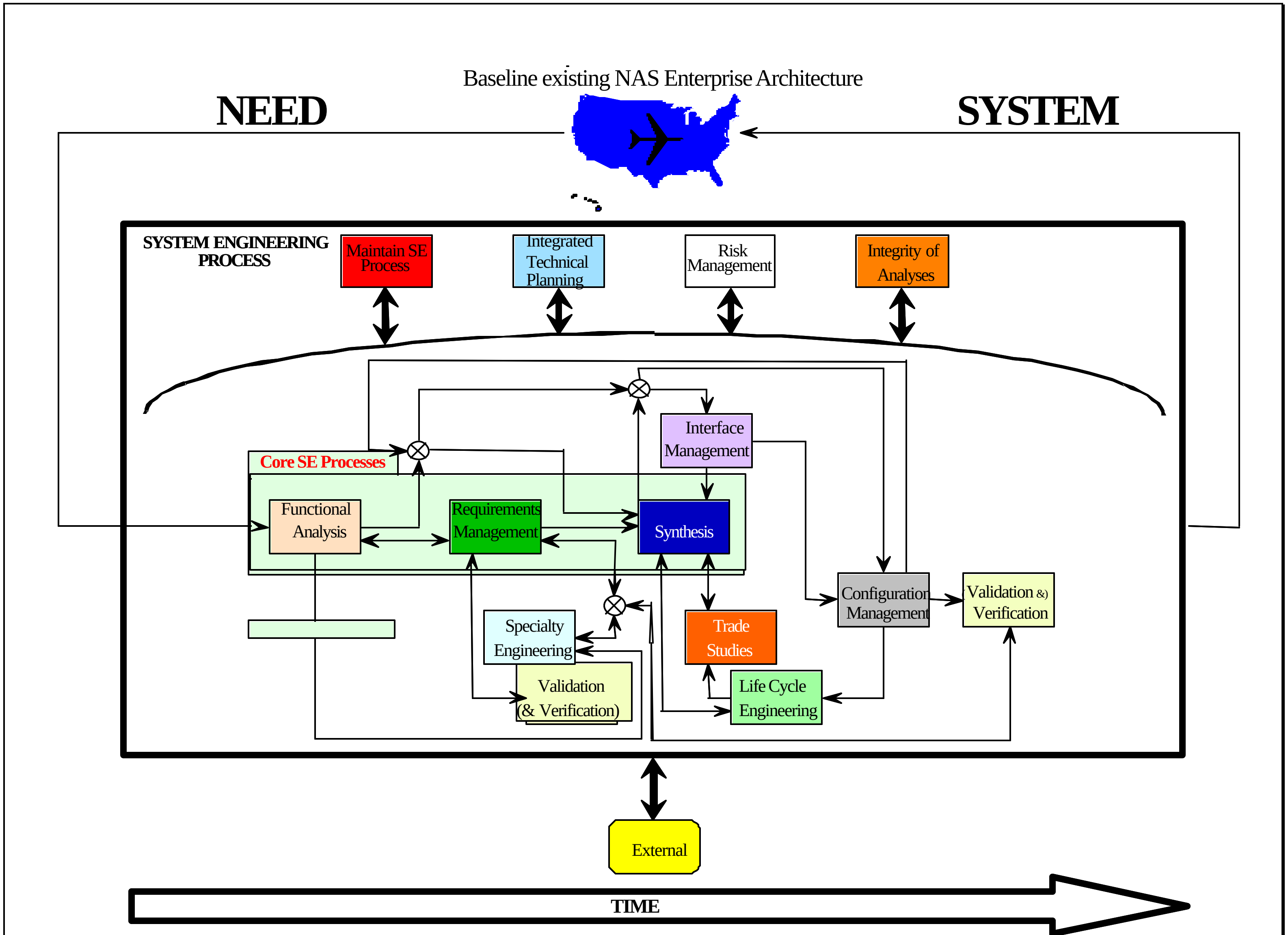

Figure 4.1-1. Functional Flow Diagram of System Engineering

In Figure 4.1-1, each SE process is laid out from left to right to notionally depict when in time each process is employed relative to another. The time arrow is ***not*** relative to the AMS lifecycle phases. Note that overall SE, and many of the interactions at the lower levels, may be iterative in nature; thus, the left-to-right timeline is notional.

Figure 4.1-1 indicates that SE is initiated when there is a need; that is, a recognized shortfall in capability within the NAS. One of the tools or products used to determine need or identify a shortfall in service capability is the National Airspace System (NAS) Enterprise Architecture (EA). The EA defines the mission, the information necessary to perform the mission, and the technologies necessary to perform the mission. It is used to manage change when implementing new technologies in response to changing mission needs. The EA includes a baseline architecture (or existing NAS), target architecture(s), and a transition plan. It is divided into a number of views or perspectives on the information in the architecture. As presently defined, the FAA EA builds on the approach that the U.S. Department of Department (DoD) uses to define its EA, the DoD Architecture Framework (DoDAF). There are three types of views in the DoDAF: the all views (AV), the operational views (OV), and the system view (SV). The AV states the purpose of the architecture and provides an integrated dictionary. The OV provides the specification of tasks, operation elements, and information exchanges required to accomplish the mission. The OV also defines the types of information exchanges, the frequency of exchange, which activities are supported by the information exchanges, and the maturity of the information exchanges. The SV describes the system(s) and interconnections providing for or supporting FAA functions and associated systems resources to the operational activities to facilitate the exchange of information among operational nodes (e.g., facilities). Each subsequent Chapter 4 section (Sections 4.2 through 4.14) will describe the EA product(s) that directly or indirectly relate to that particular SE process element and products.

Stakeholder needs may arise as a result of a new service to be provided or with the advent of technological innovations to be leveraged to reap improvements in capacity, efficiency, security, and/or safety. Once the need is validated, the Functional Analysis process (Section 4.4) is performed to develop Concepts (see Figure 4.1-1). The Requirements Management process (Section 4.3) uses the Concept of Operations to develop a Service Level Mission Need, which is then fed back to Functional Analysis as input to develop the highest level of functional architecture for the new or modified system. The Requirements Management process uses this high-level functional architecture, as well as inputs from Specialty Engineering analyses, to develop requirements. The Validation and Verification process (Section 4.12) validates these requirements. Interaction between Functional Analysis and Requirements Management is iterative, as the functional architecture and resulting requirements are decomposed to a level necessary to the appropriate requirements that describe the needed system characteristics. Synthesis (Section 4.5) then develops the physical architecture or design solution to those requirements.

Along with these initial SE activities, three overarching processes that interact with all SE processes are employed. These processes, which continue throughout the system's lifecycle, are as follows:

- Integrated Technical Planning (Section 4.2)
  - Provides the technical guidance tools required to track and manage program activity
- Risk Management (Section 4.10)

  - Provides an organized, systematic decision-making approach to identify risks that affect achievement of program goals
  - Analyzes identified risks
  - Mitigates risks effectively
  - Tracks the progress of the mitigation efforts
- Integrity of Analyses (Section 4.9)
  - Ensures provision of credible, useful, and sufficient data/results for program management's decision-making process
  - Ensures the integrity and fidelity of the various analysis tools

Once a valid set of requirements is obtained, the Synthesis process (Section 4.5) is initiated to define system elements and to refine and integrate these elements into a physical architecture. In addition to the requirements input into the Synthesis process, the functional architecture is provided to clarify and bound the system. The Trade Studies process (Section 4.6) and the Lifecycle Engineering process (Section 4.13) supply cost estimates to support the Synthesis process, which ultimately determines the design alternative that best satisfies the identified stakeholder need.

Interface Management (Section 4.7) plays a key role in ensuring that the various internal system pieces are coordinated as well as integrated with external systems. As the total system is decomposed via iterative interaction of Functional Analysis, Requirements Management, and Synthesis, physical and functional interfaces are identified and managed.

The results of these SE activities are continually placed under Configuration Management (Section 4.11). The system is developed according to the baseline design and verified with the Validation and Verification process (Section 4.12). With the system verified as able to meet the identified stakeholder need, it is deployed into the NAS. Although the discussion of this simplified view and description of SE was sequential, SE is truly iterative and employed continuously throughout the lifecycle of the system.

When used properly, SE creates an infrastructure that ensures that customer requirements and expectations are effectively and efficiently identified, integrated, and managed. Because the primary objective of SE is to provide a balanced view of needs and solutions, the integration dimension of this effort should not be underestimated. **Integration is defined as the progressive linking and testing of system components to merge their functional and technical characteristics into a comprehensive, interoperable system.**[1] From a process perspective, it can be viewed as the conduits connecting the elements, as well as the overall SE framework to its environment, in Figure 4.1-1. From a system perspective, it can be viewed as the glue that binds the various elements of a product, transforming it from a confederation of loosely related items to a tightly coupled entity.

Each SE element is capable of maximizing the thoroughness and quality of interaction and cooperation between individuals, teams, suppliers, and stakeholders as each SE element is performed. In addition, each SE element plays various roles throughout the lifecycle phases as shown in Table 3.2-1 (Chapter 3). The following subsections provide an overview of each SE

[1] Institute for Telecommunications, U.S. Dept of Commerce.

element regarding its objective, definition, and value. The subsequent sections of the manual (Sections 4.2 through 4.14 and the appendices) extensively document each SE element and contain these details:

- Process-Based Management (PBM) chart (objectives, inputs, and associated providing process (providers); outputs and associated receiving process (customers); process tasks; and applicable lifecycle phases)
- Process workflow
- Methods, tools, and detailed descriptions of how the tasks of each SE element are accomplished
- Steps to tailor the SE element
- Appendices for terms, acronyms, and work product examples

4.1.2 Summary of System Engineering Areas

The following subsections briefly summarize FAA SE and its 13 elements. The bracketed information under each subsection heading provides a cross-reference to the applicable section number and the relevant integrated Capability Maturity Model (iCMM) process areas. The iCMM uses process areas to describe the process attributes. Process areas group together base practices related to achieving goals and a common purpose. Table 4.1-1 lists the iCMM Process Areas.

Table 4.1-1. iCMM Process Areas

PA 00 Integrated Enterprise Management	PA 12 Supplier Agreement Management
PA 01 Needs	PA 13 Risk Management
PA 02 Requirements	PA 14 Integrated Teaming
PA 03 Design	PA 15 Quality Assurance and Management
PA 04 Alternatives Analysis	PA 16 Configuration Management
PA 05 Outsourcing	PA 17 Information Management
PA 06 Design Implementation	PA 18 Measurement and Analysis
PA 07 Integration	PA 19 (reserved for future use)
PA 08 Evaluation	PA 20 Process Definition
PA 09 Deployment, Transition, and Disposal	PA 21 Process Improvement
PA 10 Operation and Support	PA 22 Training
PA 11 Project Management	PA 23 Innovation

4.1.2.1 System Engineering

[SEM 4.1; iCMM PA 01 through 05, 07 through 14, 16, and 20 through 23]

4.1.2.1.1 Objective

The objective of SE within the FAA is to consistently provide balanced solutions to complex FAA system needs.

4.1.2.1.2 Definition

> *SE is a discipline that concentrates on the design and application of the whole (system) as distinct from the parts. It involves looking at a problem in its entirety, taking into account all the facets and all the variables and relating the social to the technical aspect.*

SE defines how the organization discerns a problem, how it approaches developing a solution to a problem, and how it implements the plan to enable resolution of the problem.

4.1.2.1. 3 Value

While SE process elements support the cycle defined by the Acquisition Management System (AMS), they also provide a finer, more detailed breakdown that provides better management visibility into the operation of the program. This leads to earlier identification of issues, problem correction, and better identification of requirements, which reduces risk as well as cost. Support organizations are better able to gauge and plan their work to support each phase.

4.1.2.2 Integrated Technical Planning

[SEM 4.2; iCMM PA 11, 21, 22, 23]

4.1.2.2.1 Objective

The Integrated Technical Planning element (Section 4.2) seeks to provide program management with specific guidance and direction on how to plan a program's execution resulting in a sound, repeatable method for performing a requirements-based and structurally managed program. It also provides a feedback mechanism (subsection 4.2.6) to measure or assess progress against a plan, identifies variances, and provides sufficient information for informed decision making on corrective action(s) to be taken.

4.1.2.2.2 Definition

Integrated Technical Planning is the tactical and strategic means of defining problems, forecasting conditions, and coordinating program elements to maximize program focus on providing superior products and services.

The technical plans provide stakeholder- and contract-driven tailoring of SE to optimally satisfy program needs. These plans are living documents that are kept current throughout the program's lifecycle.

Technical reviews and audits are the primary means to monitor and control performance to the technical plans. They provide insight into the readiness of a program to proceed to each subsequent phase of the system's lifecycle.

4.1.2.2.3 Value

Various levels of technical and program management use the technical plans that result from Integrated Technical Planning. Expending upfront effort to generate clear, complete, and correct technical plans results in consistent performance across the program. A consistent focus on monitoring implementation progress reduces the risk of missing program objectives. Optimally, miscommunication and misinterpretation of stakeholder and executive expectations by individuals are eliminated. Developing and following properly prepared plans assist in eliminating miscommunication and helps the program to adapt to changes in program environment.

4.1.2.3 Requirements Management

[SEM 4.3; iCMM PA 01 and 02]

4.1.2.3.1 Objective

The Requirements Management element (Section 4.3) seeks to identify and develop all requirements and ensure that they are met throughout the product's lifecycle. It 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
- Allocates the requirements to the appropriate component within the system hierarchy and/or to the appropriate organizational entities
- Derives lower level requirements from higher level requirements in the system hierarchy
- 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

4.1.2.3.2 Definition

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, and verifiable manner. 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.

The Requirements Management element consists of a series of iterative tasks that a multifunction team performs throughout all AMS phases. The team's focus is to elicit, develop, manage, and control requirements and associated documentation. Once the team defines the requirements, it uses a disciplined Requirements Management methodology to manage the requirements set, helping to ensure compliance with stakeholder needs and expectations, communication of allocations, and adaptation to/control of changes.

4.1.2.3.3 Value

Requirements fuel the design process. They define the characteristics of a system at all levels of complexity. They are derived from multiple inputs from internal and external sources that need to be logically and efficiently collected and synthesized in a centralized, accessible decision database. The information collected, managed, and controlled is accessed by various teams within the stakeholder and program organizations, associated internal interfaces (e.g., management or operations), and contractors/suppliers. When Requirements Management is performed well, rework and poorly communicated information typically is minimal, if not eliminated entirely. Furthermore, this process is used to reveal gaps, redundancies, biases, and/or inconsistencies and resolve, revise, and/or refine them in a consistent, integrated method that satisfies all the stakeholders. The solid foundation built through Requirements Management provides an ongoing resource for all program stages.

4.1.2.4 Functional Analysis

[SEM 4.4; iCMM PA 03 and 04]

4.1.2.4.1 Objective

The Functional Analysis element (Section 4.4) seeks to provide a framework for developing requirements and physical architectures that significantly improves innovation, synthesis of design, requirements development, and product integration.

4.1.2.4.2 Definition

Functional Analysis translates stakeholders' needs into a sequenced and traceable functional architecture. It pinpoints innovative design solutions and sheds light on vague interfaces. It also provides the basis for logical and realistic product integration and synthesis. As the analyses are performed, additional requirements often are flushed out/derived, thereby providing the program a more detailed list of requirements and an increased understanding of the system. The functional architecture defines what the system does, including interfaces (both within the system and to the external world).

4.1.2.4.3 Value

The Functional Analysis process provides two key benefits to SE: It discourages single-point solutions, and it describes the behaviors that lead to requirements and physical architectures. The functional architecture and functional interfaces enable the stakeholders and program management to logically develop requirements down to the lowest level of a system hierarchy.

4.1.2.5 Synthesis

[SEM 4.5; iCMM PA 03 and 04]

4.1.2.5.1 Objective

The Synthesis element (Section 4.5) seeks to define design solutions and identify systems that will satisfy the program requirements. Synthesis translates the requirements, as set in context by the functional architecture, into the design architecture, consisting of the physical architecture with its associated technical requirements.

4.1.2.5.2 Definition

Synthesis is the creative process that translates requirements (performance, function, and interface) into alternative solutions. This results in a physical architecture for the "best-value" design solution composed of people, products, and process solutions for the logical, functional grouping of the requirements.

The synthesized design generated is a balanced (i.e., cost, quality, schedule, risk, performance, producible/supportable) solution and is created through analysis of candidate elements. The candidate elements are preliminarily defined and then iteratively defined down to lower, more detailed levels until refinement of the system concept is complete.

4.1.2.5.3 Value

A series of benchmarks for various design performance parameters (e.g., power, data storage, testability, and reliability) are generated and used to measure the viability and worth of a candidate design solution. Design performance parameters, ranked by importance, are refined during the design evolution of an affordable, responsive system design. Throughout the evolutionary analyses, credibility and acceptability by the stakeholders shall be ensured. The iterative nature of the candidate element task provides the mechanism to continuously correct design inadequacies and to refine the physical allocation process. The task also provides opportunities for new technologies and innovative ideas to be considered, justified, and integrated. These efforts are used to validate the synthesized design in terms of balance, completeness, understandability, and reflection of the stakeholders' requirements.

4.1.2.6 Trade Studies

[SEM 4.6; iCMM PA 04]

4.1.2.6.1 Objective

The Trade Studies element (Section 4.6) seeks to select the most balanced (i.e., cost, schedule, quality, and risk) solutions from a set of proposed viable alternatives based on defined criteria.

4.1.2.6.2 Definition

Multidisciplinary teams use the Trade Studies element to confirm that the most balanced technical solutions have been identified. The team methodically evaluates a series of design alternatives and recommends the preferred feasible solutions that enhance the value and performance of the overall system and/or functions. The team details each assessment to an appropriate level that allows differentiation between alternatives. The team develops recommendations and forwards them in a trade study report to the appropriate decision maker(s) (e.g., program management or stakeholders) for action.

4.1.2.6.3 Value

Trade Studies element tasks are designed to assist decision makers. The thorough identification and assessment of multiple facets of a problem aid the decision maker to relate the whole problem to optimal, feasible solutions by comparing technical, cost, and schedule interactions. The Trade Studies element prevents program/project management from committing too early to a design that may not be cost effective or meet all system requirements too early in the process. It provides the traceability to substantiate design and configuration changes to the baseline product design; it also documents why one alternative was chosen over another during the decision-making process. The appropriate management authority uses this information to make a final decision.

4.1.2.7 Interface Management

[SEM 4.7; iCMM PA 07]

4.1.2.7.1 Objective

The Interface Management element (Section 4.7) seeks to identify, describe, and define interface requirements to ensure compatibility between interrelated systems and between system elements, as well as provide an authoritative means of controlling the interface design.

4.1.2.7.2 Definition

Interface Management, which includes identifying, defining, and controlling interfaces, helps to ensure that all the pieces of the system work together to achieve the system's goals and continue to operate together as changes are made during the system's lifecycle.

An interface is the performance, functional, and physical attributes required to exist at a common boundary. It may be external, internal, functional, or physical. Interfaces occur within the system (internal) as well as between the instant system and another system (external).

The Interface Requirements Document (IRD) records interface requirements. The Interface Control Document (ICD) contains the "as built" design of how the contractor implements the requirements.

4.1.2.7.3 Value

During the program's life, compatibility and accessibility shall be maintained for the many diverse elements. Compatibility analysis of the interface definition demonstrates completeness of the interface and traceability records (or lack thereof). As changes are made, an authoritative means of controlling the design of interfaces shall be managed with appropriate documentation, thereby avoiding the situation in which hardware/software, when integrated into the system, fails to function as part of the system as intended. Ensuring that all system pieces work together is a complex task that involves teams, stakeholders, contractors, and program management, from the end of the initial concept definition stage through the operations and support stage.

4.1.2.8 Specialty Engineering

[SEM 4.8; iCMM PA N/A]

4.1.2.8.1 Objective

The Specialty Engineering element (Section 4.8) seeks to: (1) integrate specific system attributes and disciplines into the acquisition process; and (2) assess and confirm various system attributes (Specialty Engineering).

SE relies on specialty domain expertise to define and characterize specific requirements. SE's function in this process is to integrate the design engineer's activities and specialty engineer's activities; coordinate and open communication lines between the design engineer and specialty engineer; and focus the engineering effort on meeting the common goal of satisfying the customer.

4.1.2.8.2 Definition

The Specialty Engineering element defines and evaluates a system's specific areas, features, or characteristics as related to the specialty engineering aspects of the system. Specialty Engineering analyses describe technical details of the design from a particular perspective and often require specialized skills. Table 4.1-2 describes, generally, the Specialty Engineering disciplines.

Table 4.1-2. Specialty Engineering Disciplines

Specialty Engineering Discipline	Description
System Safety Engineering (SSE)	Evaluation and management of the safety risk associated with a system using measures of safety risk identified in various hazard analyses, fault tree analyses, safety risk assessments, and hazard tracking and control.
Reliability, Maintainability, and Availability (RMA)	Quantitative and qualitative analyses of the attributes to optimize the RMA performance of a system within the program's operational and programmatic constraints throughout the system lifecycle. Qualitative analyses are in the form of failure mode assessments. Evaluation of the design's ability to meet operational readiness requirements through preventive and corrective maintenance.
Human Factors Engineering (HFE)	Human factors is a multidisciplinary effort to generate and compile information about human capabilities and limitations and apply that information to: – equipment, systems, facilities – procedures, jobs, environments – staffing – training – personnel and organizational management for safe, comfortable, and effective human performance.

Specialty Engineering Discipline	Description
Electromagnetic Environmental Effects (E^3)	Analysis of the system for susceptibility and/or vulnerability to electromagnetic fields or capability to generate such fields that might interfere with other systems and to identify sources of interference and means for correction within the levels prescribed by law, program requirements, spectrum management, or recognized standards. E^3 is composed of Electromagnetic Interference (EMI) and Electromagnetic Compatibility (EMC)
Quality Engineering (QE)	An objective analysis of all planned and systematic activities to ensure that a product or service fulfills requirements and is of the highest quality.
Information Security Engineering (ISE)	Evaluation of the vulnerability of the system to unauthorized access and use or susceptibility to sabotage. Assessment of the ability of the system to survive a security threat in the expected operational environment.
Hazardous Materials Management/Environmental Engineering	Determination of environmental impacts at deployment sites and during operations, including both environmental impacts on the system and system impacts on the environment during all phases of the product life.

4.1.2.8.3 Value

Specialty Engineering outputs are often used to validate and/or verify requirements and support technical decision on a program. In addition, change proposal documentation is produced if the conclusions of the analysis call for a revision to the Requirements or design baseline.

These analyses are used to support functional analysis (Section 4.4); define, allocate, and validate requirements (Section 4.3); contribute to the design (Section 4.5); and to evaluate design progress, technical soundness, and risk. Stakeholders also need them to ensure that the product performs as intended (Section 4.12), and engineering, operations, and product support personnel need them to accomplish their responsibilities in product development and operation.

These analyses help the program to define requirements and design features and/or describe characteristics of the design and related operations in support of Validation and Verification (Section 4.12), Requirements Management (Section 4.3), Trade Studies (Section 4.6), Synthesis (Section 4.5), and Functional Analysis (Section 4.4).

4.1.2.9 Integrity of Analyses

[SEM 4.9; iCMM PA N/A]

4.1.2.9.1 Objective

The Integrity of Analyses element (Section 4.9) seeks to provide systematic guidance that leads to analysis results that are credible, useful, sufficient, and verifiable.

4.1.2.9.2 Definition

Analysis is defined as a logical examination or study of a system to determine the nature, relationships, and interaction of its parts and environment.

Integrity of Analyses is defined as a disciplined process applied throughout a program to ensure that analyses provide the required levels of fidelity, accuracy, and confirmed results in a timely manner.

4.1.2.9.3 Value

Analyses are constantly being performed throughout SE and the program's lifecycle. These analyses range from simple to complex, quantitative to qualitative, top-down to bottom-up, and basic formulas to sophisticated simulations. To ensure credible, useful, sufficient, and timely data/results for program and/or technical decisions, the integrity and fidelity of the various analysis tools shall be understood and validated. This validation takes several forms: the attributes of the tool suite, validity of the input data, and proficiency and workmanship of the analyst. An Analysis Management Plan is generated that outlines the details of the various analysis methods and tools. It is recommended that this plan also reflect the program's constraints regarding technical capabilities, schedule requirements, and cost requirements.

The initial selection of the method, tools, or model to be used in an analysis focuses on determining a practical tool that provides the most visibility into the problem with the least complexity. Because this process is iterative, there is an ongoing need to use the best approach to select the right method, tool, or model, considering the preferences of the stakeholders, other teams' previous experience with different tools, and the limitations of budgets, technology, and schedule.

The bottom line is to have analyses in place that guard against mistakes and embed a consistent level of confidence in the integrity of the analysis. The analysis, in turn, contributes significantly to the success of the decision-making processes of program management, teams, stakeholders, and contract managers.

4.1.2.10 Risk Management

[SEM 4.10; iCMM PA 13, 14, 18]

4.1.2.10.1 Objective

The Risk Management element (Section 4.10) seeks to identify and analyze the uncertainties of achieving program or organizational objectives and develop plans to reduce the likelihood and/or consequences of those uncertainties.

Four lower level objectives are:

- Timely identification of risks (identifying a potential problem, with sufficient lead time so that the team may implement appropriate alternate plans)

- Consistent assessment of the level of risk across a program (providing a structured decision-making framework for prioritizing resource application)

- Communication of risk mitigation actions across the program/organization (ensuring that all elements of the program/organization are aligned in resolving risks)

- Review of risk mitigation action performance

4.1.2.10.2 Definition

Risk Management is an organized, systematic decision-support process that identifies risks, assesses or analyzes risks, and effectively mitigates or eliminates risks to achieve program or organizational objectives.

Risk is defined as a future event or situation with a realistic (non-zero nor 100 percent) likelihood/probability of occurring and an unfavorable consequence/impact to the successful accomplishment of well-defined goals if it occurs.

Risk Management seeks to understand and avoid the potential cost, schedule, and performance/technical risks to a project, and to take a proactive and well-planned role in anticipating them and responding to them if they occur. Risk Management is equally at home in project management as well as System Engineering because both domains have a common view of seeking out opportunities to solve a problem or fulfill a need. Opportunity represents the potential for improving value in achieving a goal; risk represents the potential for decreasing the same value. Hence, any discussion of Risk Management should include opportunity management. The methodologies, decision parameters, and outcomes apply as well to risks as they do to opportunities.

4.1.2.10.3 Value

Understanding the levels of likelihood and consequences of risk occurring increases the program manager's and program team's ability to anticipate and control the impacts of internal and/or external events on their programs. These impacts include, but are not limited to, cost, quality, schedule, and stakeholder satisfaction trends. The comprehensiveness of the analysis drives the thoroughness of what resources are required to mitigate the risk (e.g., budgets, requirements changes, stakeholder interfaces). Risk identification worksheets, tools, and terminology ensure a consistent approach that generates an analysis in which subjectivity is minimized, and confidence in the analysis is maximized.

4.1.2.11 Configuration Management

[SEM 4.11; iCMM PA 16]

4.1.2.11.1 Objective

The Configuration Management element (Section 4.11) seeks to establish and maintain consistency of a product's performance, functional, and physical attributes with its requirements, design, and operational information throughout its life.

4.1.2.11.2 Definition

Configuration Management (CM) is defined as "a management process for establishing and maintaining consistency of a product's performance, functional, and physical attributes with its requirements, design and operational information throughout its life." [2] The discipline provides a structured approach to identify, control, and maintain the configuration of a system/product during its lifecycle through establishment of baselines. A baseline is an agreed-to description of the attributes of a product at a point in time that serves as a basis for defining change. CM enables organizations to ensure the integrity of their products through all lifecycle phases.

The tasks focus on consistency of requirements, design, and operational information throughout the product's life. Once baselined as defined by stakeholder requirements, changes are systematically approved and managed to ensure that traceability/accountability is maintained throughout myriad levels of documentation. The planning and execution of CM includes five fundamental practices: (1) plan CM process, (2) identify baseline elements, (3) manage approved baseline elements, (4) provide configuration status accounting, and (5) verify and audit configuration.

4.1.2.11.3 Value

Configuration Management benefits the program, stakeholders, and contractors/suppliers. The discipline provides a structured approach to identify, control, and maintain the configuration of a system/product during its lifecycle through establishment of baselines. CM enables organizations to ensure product integrity through all lifecycle phases. As product attributes are defined, measurable performance parameters may be established for the product's acquisition and use. As changes are made, Configuration Management provides correct and current information to the decision-making process. When configurations are managed, product repeatability is enhanced, guesswork and downstream surprises are avoided, cost and schedule savings are realized, erratic changes are minimized, proper replacement and repairs are ensured, and maintenance costs are reduced. The overall effect is establishment of a high level of confidence in the product information.

4.1.2.12 Validation and Verification

[SEM 4.12; iCMM PA 08]

4.1.2.12.1 Objective

The Validation and Verification element (Section 4.12) seeks to determine that the system and process requirements are correct and have been met.

Validation is performed to ensure the correctness and completeness of the requirements that define a solution. The objectives of the Validation process include:

- Developing the Validation Table and inclusion of the Validation Table in a Validation Report

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[2] ANSI/EIA-649-1998, National Consensus Standard for Configuration Management.

- Appending to or referencing by the existing requirements documents of the Validation Report
- Confirming that the system services required are properly documented in the program requirements
- Confirming that the requirements resulting from the service-level gap analysis faithfully describe the required system functions.
- Reporting nonconformance, used to identify corrective actions
- Ensuring traceability of all requirements to the top-level program requirements
- Documenting the program's concerns and issues and constraints

Verification proves that a system is able to demonstrate (show evidence) that it complies with the Service Level Mission Need; functional, performance, allocated, derived, and interface requirements; and design and allocated constraints that provide the solution to the service gap analysis. The major objectives of the Verification process are:

- Intended functions are correctly implemented and that the system is operationally ready and acceptable to the users
- Requirements are satisfied
- Specialty Engineering analyses, including lifecycle, remain valid for the system as implemented

4.1.2.12.2 Definition

The Validation and Verification element ensures that all system requirements are correct and have been met. The Validation process proves that the right system is being built (i.e., that the requirements are unambiguous, correct, complete, consistent, operationally and technically feasible, and verifiable).

The Verification process ensures that the designed solution has met the system requirements and that the system is ready for use in the environment for which it is intended.

4.1.2.12.3 Value

The Validation process is conducted to provide objective evidence that the functionality of the solution, as defined in the program requirements, complies with the Service Level Mission Need. When variances are identified, they are recorded and used to guide corrective actions. Because Validation is a comparative assessment of the need and the requirements, it also confirms the service gap analysis.

The Verification process confirms that the development process has provided a solution that is consistent with stakeholder needs and compliant with the program's validated requirements. It is a basic principle to verify all requirements in the program requirements.

4.1.2.13 Lifecycle Engineering

[SEM 4.13; iCMM PA 05, 09, 10, 12]

4.1.2.13.1 Objective

The Lifecycle Engineering (LCE) element (Section 4.13) seeks to meet the cost and performance objectives of a system during its entire lifecycle. Programs provide services that may be obtained from systems as well as systems of systems having multiple system elements (e.g., system of systems).

4.1.2.13.2 Definition

LCE objectively evaluates the constraints and dependencies associated with developing and operating a product or service, while seeking to maximize the product or service's value while minimizing the cost of ownership of the product or service over the entire lifecycle. The lifecycle includes the entire spectrum of activity for a given system, beginning with identification of a need and extending through a system design and development, production and construction, operational use, sustainment of support and system retirement, and, eventually, disposal.

4.1.2.13.3 Value

LCE manages costs from inception (cradle) to disposal (grave) for equipment and projects over their anticipated useful life span. LCE aims at providing an engineering discipline that provides best results when both art and science are merged with good judgment. These analyses are used to evaluate design progress, technical soundness, and risk. They are also needed by the stakeholders to ensure that the product performs as intended, as well as by engineering, operations, and product support personnel to accomplish their responsibilities in product development and operation.

4.1.2.14 System Engineering Process Management

[SEM 4.14; iCMM PA 20 and 21]

4.1.2.14.1 Objective

The System Engineering Process Management element (Section 4.14) has three objectives:

- Maintain and improve SE processes contained in the SEM
- Train the workforce on the SE processes by managing the SE training materials and ensuring that they accurately reflect the processes described in the SEM
- Incorporate process innovation

4.1.2.14.2 Definition

System Engineering Process Management provides support and balance for the 12 other SE process elements. It also includes activities to measure and improve the SE process elements, which involve designing, developing, improving, and maintaining definitions of SE activities, work, products, methods, techniques, practices, and tools. It additionally provides the technology environment for developing systems and performing SE.

4.1.2.14.3 Value

This process provides the details and data to ensure and improve overall SE efficiency and effectiveness. In turn, improved SE reduces cost and schedule while improving NAS efficiency and safety.