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1 July 2013

Supersedes:
SMC-S-001 (2010)

Air Force Space Command

SPACE AND MISSILE SYSTEMS CENTER STANDARD

SYSTEMS ENGINEERING REQUIREMENTS AND PRODUCTS

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FOREWORD

1. This standard defines the Government's requirements and expectations for contractor performance in defense system acquisitions and technology developments.

2. This revised SMC standard comprises the text of The Aerospace Corporation report number TR-0001 dated 28 February 2013, entitled *Systems Engineering Requirements and Product,* and contains the following major changes:

- Test Like You Fly requirements, as reviewed by industry and documented in The Aerospace Corporation report TOR-2012(1315)-3, Rev A, dated 12 December 2012.
- Human Systems Integration requirements, as reviewed by industry and documented in The Aerospace Corporation report TOR-2012(8960)-1, Rev A, dated 12 August 2012. [Note: reformatted from a standalone document to Section 4.3.11 of this document.]
- Update of referenced documents to current versions.
- Minor editorial updates and corrections reported by users.

3. Beneficial comments (recommendations, changes, additions, deletions, etc.) and any pertinent data that may be of use in improving this standard should be forwarded to the following addressee using the Standardization Document Improvement Proposal appearing at the end of this document or by letter:

Division Chief, SMC/ENE
SPACE AND MISSILE SYSTEMS CENTER
Air Force Space Command
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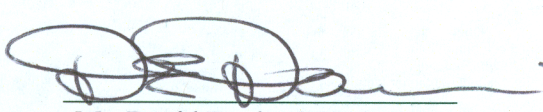
4. This standard has been approved for use on all Space and Missile Systems Center/Air Force Program Executive Office - Space development, acquisition, and sustainment contracts.



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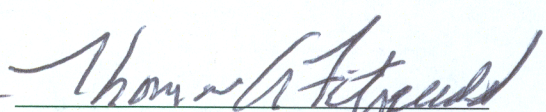

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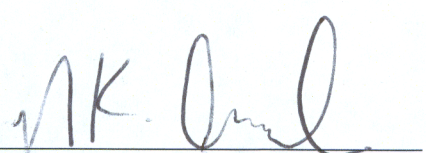

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1. Scope

1.1 Document Purpose

This standard defines the government's requirements for a disciplined systems engineering approach to system acquisitions. It specifies the government's requirements for executable contractor systems engineering efforts and can also be used as a guide by the tasking agency/activity to assist in systems engineering planning and management. Government agencies (Department of Defense and the intelligence community) should use this document as a compliance document for system acquisition contracts. It is also applicable to non-DOD government (NASA and others), civil, and commercial developments.

This document's objective is to define the essential work products, produced in the systems engineering process, needed to:

Adequately define a system over its life cycle such that the integrated system when deployed:

a. Provides at least the threshold or minimum required capabilities and requirements and is affordable, but otherwise balances capability, cost, schedule, risk, and the potential for evolutionary growth

b. Is defined by operations concepts, operational capabilities/requirements, system architectures, specifications, drawings, technical orders, training documents, maintenance facilities and equipment documents, verification and validation plans, procedures, and reports

c. Includes the documented processes that are essential to build-to, buy-to, code-to, verify-to, deploy-to, train-to, operate-to, support/sustain-to, and dispose-to over the system life cycle

d. Has system definition products satisfying this objective, referred to as the system configuration baseline

Define products that can be used throughout the intermediate development stages by the tasking and performing activities to plan, monitor, and control the progress over each phase and contract of the system acquisition program.

1.2 Document Organization

Each systems engineering functional (process) area is presented in this document using the following format:

(1) Functional area requirement

Required systems engineering products

Required product characteristics

Each general requirement stated in the requirements sections contains the contractor's requirement for performance of the specific systems engineering function/process as expressed in a "shall" statement.

Each section titled “Required Systems Engineering Products” provides a list of products required to comply with the general requirement. The section titled “Required Product Attributes” describes the characteristics of each required systems engineering product.

2. Referenced Documents

The following documents are referenced in this standard or have been used as information sources. The order of presentation does not imply an order of precedence.

- Department of Defense Directive 5000.1, May 12, 2003
- DODI 5000.02, Operation of the Defense Acquisition System, December 2, 2008 (and associated Directive Type Memorandum: DTM 09-027, Implementation of the Weapons System Acquisition Reform Act of 2009, dated December 9, 2011)
- CJCSI 3170.01G, Joint Capabilities Integration and Development System, 2009
- DOD Architecture Framework, Version 2, May 28, 2008
- DOD 5000.4-M-1, Cost Analysis Guidance and Procedures, April 18, 2007
- DOD 5010.12-M, Procedures for the Acquisition and Management of Technical Data
- DODD 4630.5, DOD Information Technology Standards Registry, May 5, 2004
- DODI 4630.8, Global Information Grid
- AFI 63-101/20-101, Integrated Life Cycle Management, March 7, 2013
- MIL-HDBK-881C, Work Breakdown Structure, October 3, 2011
- Defense Acquisition Guidebook (current version)
- SMC Systems Engineering Primer & Handbook (3rd Edition), April 29, 2005
- SMC Systems Engineering Specialty Engineering Disciplines (Volume 2, 1st Edition), October 3, 2011
- INCOSE Systems Engineering Handbook (Version 3), June 2006
- SMC-S-021, Space and Missile Systems Center Standard: Technical Reviews and Audits for Systems, Equipment, and Computer Software, September 15, 2009
- SMC-G-1202, Space and Missile Systems Center Guide: Space Flight Worthiness, October 2009
- SMC-S-016, Space and Missile Systems Center Standard: Test Requirements for Launch, Upper Stage, and Space Vehicles, 2008
- ISO 17666:2003, Risk Management
- SMC-S-013 (2008), Reliability Program
- TMCR 86-01, U.S. Air Force Technical Manual Contract Requirements, 24 February 2010
- TOR-2013(8960)-3, The Aerospace Corporation: SMC Compliance Specifications and Standards, 28 February 2013 (or current version)
- NRO Enterprise Best-Engineering-Practices Repository – NEBR (current version)
- NASA Systems Engineering Handbook, NASA Report NASA/SP-2007-6105 Rev 1, December 2007
- AIAA S-117-2010, Space Systems Verification Program and Management Process, November 2010
- DOD FAR Supplement 227.405-70, Data Requirements

- Aerospace TOR-2011(8591)-2 Volume 1, Space Vehicle Test and Evaluation Handbook, Chapter 15: Test Like You Fly – Assessment and Implementation Process for Prelaunch Mission Testing, 2012
- Aerospace TOR-2010(8591)-6, Test Like You Fly: Assessment and Implementation Process, 2010
- AFI 99-103, Capabilities Based Test and Evaluation, SMC Supplement
- Beutelschies, G., "That one's gotta work" – Mars Odyssey's use of a fault tree driven risk assessment process, *Aerospace Conference Proceedings, 2002*, *IEEE*, Volume 2, pp. 651-671

3. General Requirements

This section defines the concurrent engineering environment and required systems engineering activities, tasks, and products across the system life cycle for any system, including new development, upgrade, modification, resolution of deficiencies, or development and exploitation of technology. These tasks are to be performed throughout the system life cycle; however, the focus and outputs of the tasks will be highly dependent on when they are performed during the life cycle.

The systems engineering process is an iterative process starting with requirements analysis, proceeding to functional (logical) analysis and requirements allocation, and then to design solution (synthesis), as depicted in Figure 3-1.

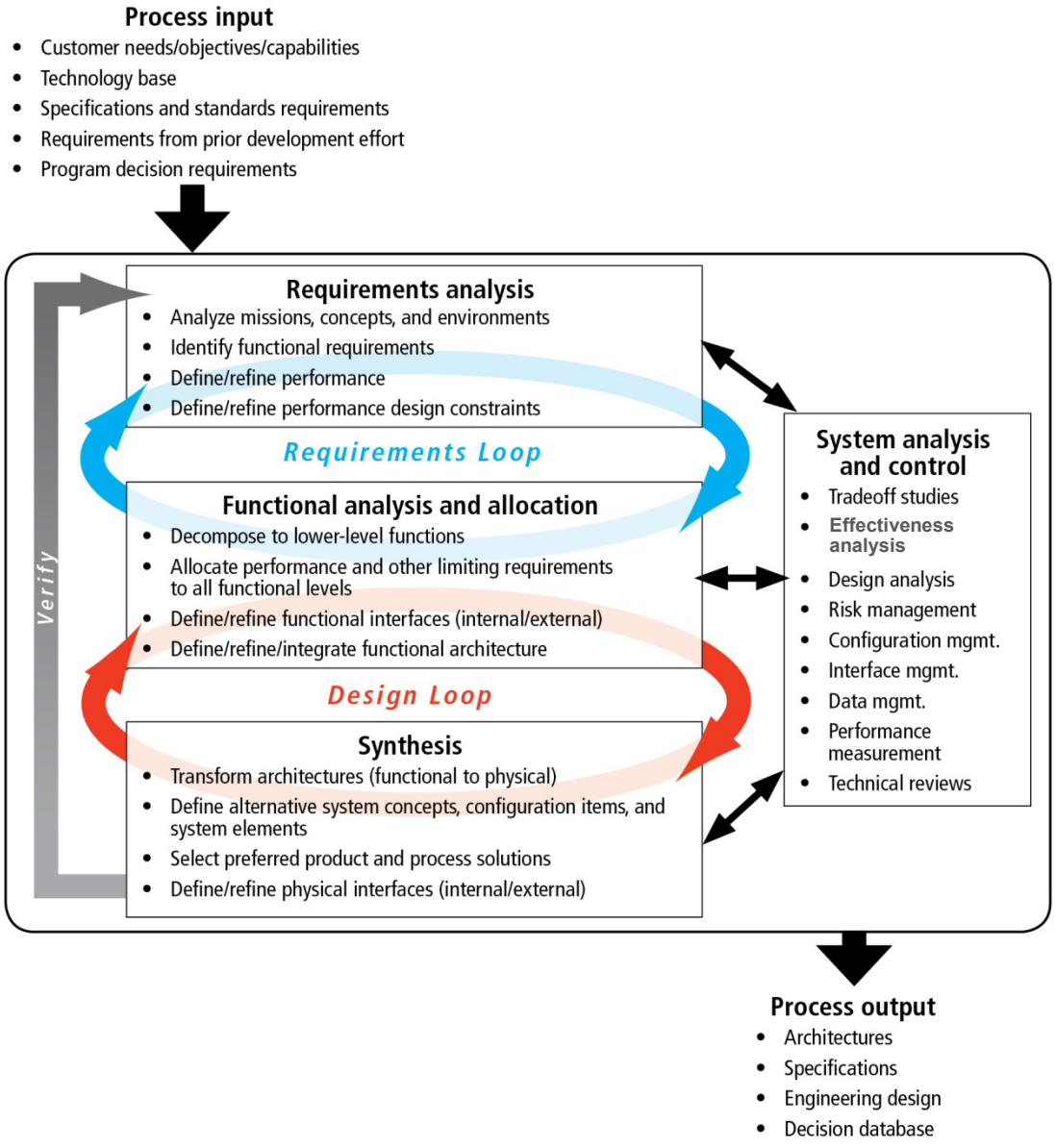

Figure 3-1. Example of systems engineering process.

Iterations can occur between these activities or via the verification and validation feedback loops. Systems analysis and control are to be performed throughout the systems engineering process. Section 5 provides the detailed requirements for systems analysis and control.

The systems engineering process also must support top-down recursions to develop the system at increasingly detailed levels and bottom-up recursion during assembly/integration. The recursive nature is further depicted in the "Vee" diagram of Figure 3-2. Both generic processes depicted in Figures 3-1 and 3-2 typically apply to the development of complex systems.

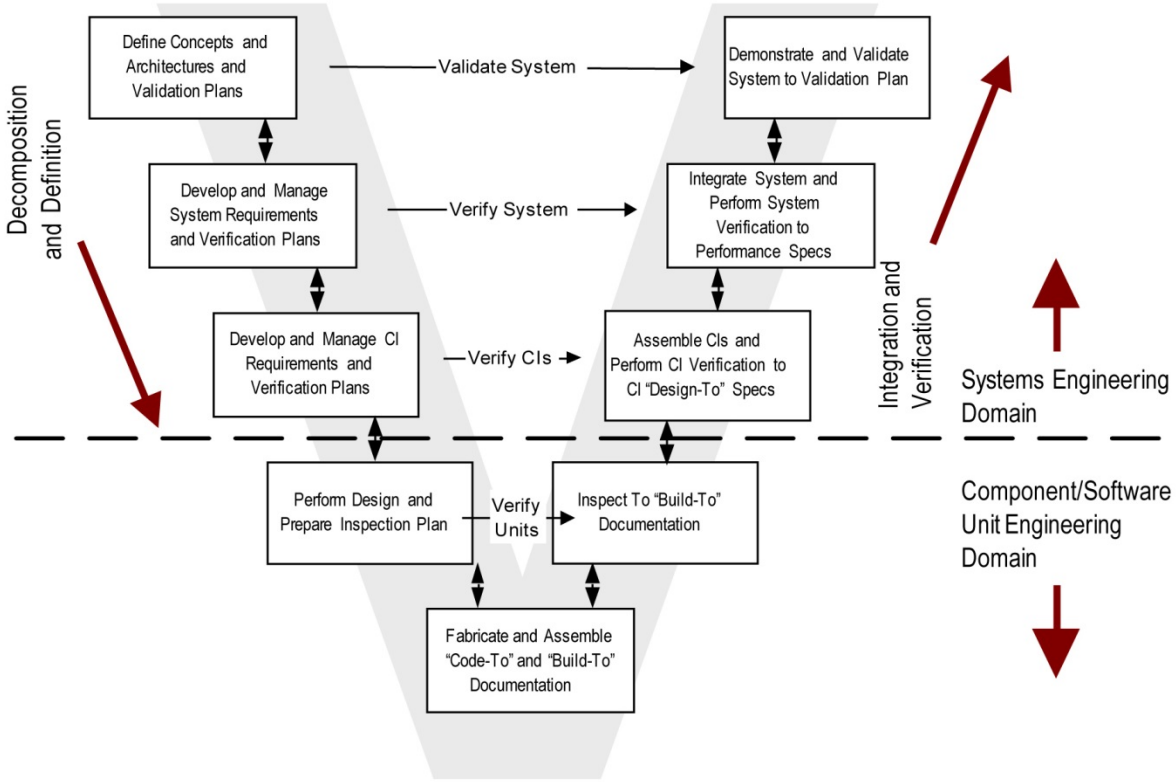

Figure 3-2. Systems engineering process described by a "Vee" diagram.

Section 3 defines the general requirements corresponding to the systems engineering (SE) activities presented in Figure 3-1. This SE activity flow is further expanded in Figure 3-3 to provide a cross-reference between the standard SE activities and the requirements presented in this document.

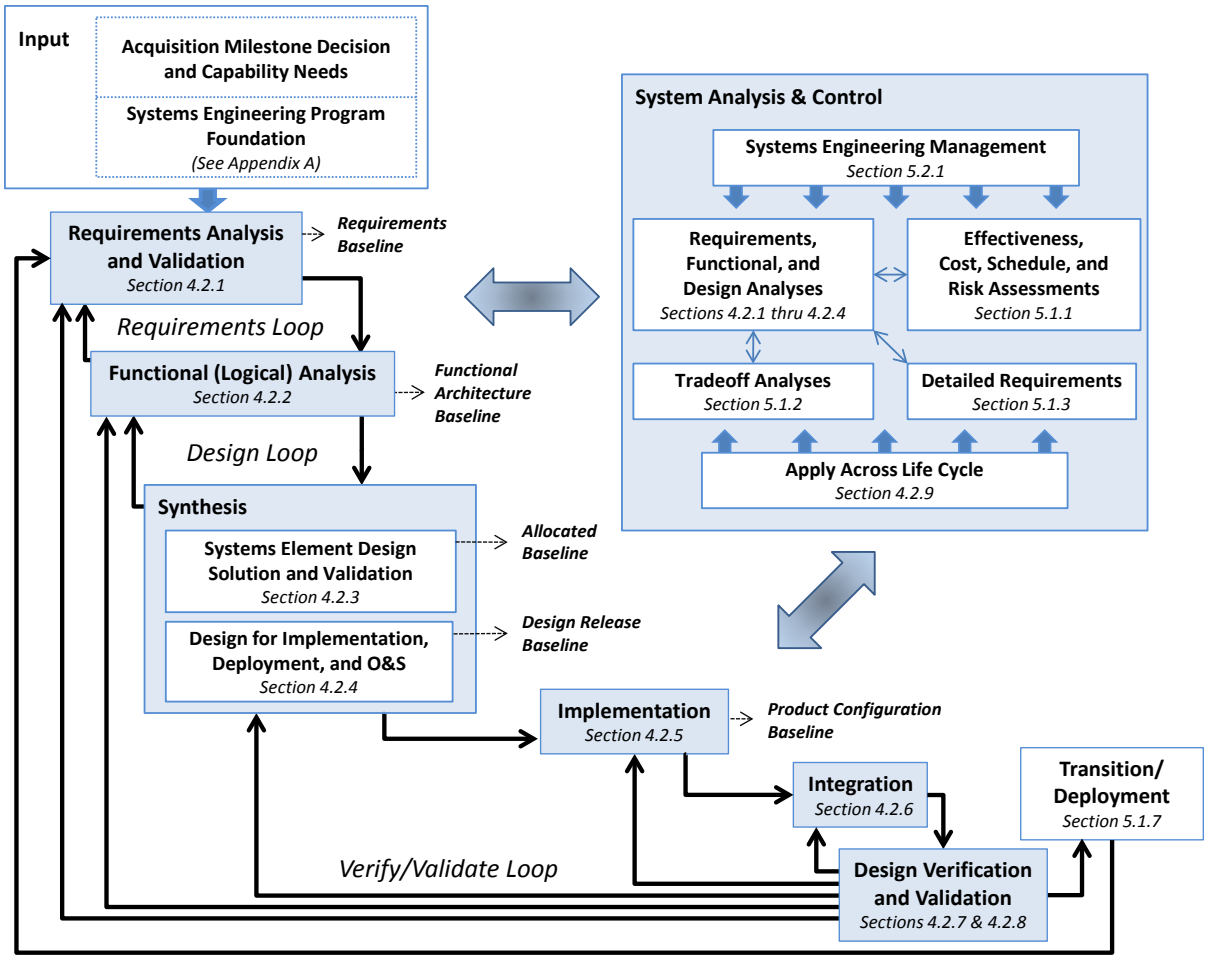

Figure 3-3. Relationship between minimum essential systems engineering requirements and baselines.

3.1 Systems Engineering Process Application

a. The contractor **shall** apply a comprehensive systems engineering process that is mutually agreeable to the contractor and contracting agency.

b. The contractor **shall** document the comprehensive systems engineering process and management plan, the Systems Engineering Management Plan (SEMP), to be used throughout the procurement and update as required.

c. The results of systems engineering process activities **shall** be captured and stored in a repository, including all analysis results, assessments, trade studies, or verification. This repository includes all decisions and the rationale for those decisions so that they can be recreated throughout the life of the program.

3.1.1 Support to the Capability Needs Process

a. The contractor **shall** participate with the customer, if contractually directed, in developing, refining, and updating:

(1) The statements of capability need thresholds and objectives corresponding to identified capability gaps.

(2) The architectural products, including the applicable operational and systems views. Apply the guidance and approaches provided in DOD Architecture Framework (current version) and/or other architectural approaches as directed by the customer and to meet specific engineering challenges and objectives.

(3) The identification of alternative materiel approaches and, for the selected materiel approach(es), alternative operational and system concepts that could fill capability gaps and that offer potential for further refinement and subsequent development.

(4) The operational scenarios and concept of operations (CONOPS) for the operational and system concepts under consideration to fill the capability gaps.

(5) The assessment of the relationship between capabilities and evolutionary growth in capabilities, on the one hand, and the life cycle cost, schedule, and risk for the materiel approaches or system concepts that could provide the capabilities, on the other hand, to highlight those capabilities that drive cost, schedule, or risk.

(6) The development of approaches for transitioning from a current system, if any, which is ultimately to be replaced, curtailed, or supplemented by the new capability.

(7) The definition of technology developments and other risk mitigation steps for potential future action toward the development of promising system concepts.

(8) Sustainment strategies.

(9) Definition of the threat environment (based on and referenced to Defense Intelligence Agency (DIA) or Service Technical Intelligence Center approved documents)

(10) Operational test and Like You Fly test planning.

(11) Assignment of mission objectives to priority levels.

b. The contractor **shall** immediately bring any inconsistencies identified between the above systems requirements and the activities of the government's capability needs or operational capability requirements process to the attention of the customer's contracting officer.

3.1.2 System-Level Constraints, Concepts, and Architectures

Using the data forming the systems engineering process foundation (see Appendix A) that have been provided or approved by the government, the development contractor **shall** define the initial system concepts to be used as inputs to the system engineering process and develop the associated required systems engineering products with the product attributes specified in this document.

3.1.2.1 Required Systems Engineering Products

a. Validated, approved, and maintained integrated architectural views that characterize interrelationships between the system and its elements and the interoperability of the system with other system, units, and forces.

b. Source and basis for engineering, including tradeoffs or other analysis for each architectural selection.

3.1.2.2 Required Product Attributes

a. The architecture products:

(1) Represent the system and its integration to achieve the operational capability requirements and to support engineering trades and analyses.

(2) Trace to the allocated functional and physical elements from which the architectural elements are derived.

(3) Trace to the capabilities for which the system is being designed and to the missions for which it is intended. Traceability is to be maintained in both directions—top-down and bottom-up—to identify requirements without parents and requirements that don't spawn children. This traceability between mission, capability, and architecture characteristics is to be maintained and kept up to date at all times.

(4) Include required architecture products defined in the DOD Architecture Framework (DODAF).

(5) Include standards contained in the current approved version provided by the DOD Information Technology Standards Registry (DISR).

(6) Provide an integrated architecture for interoperability that extends and is consistent with any architectural views provided by the customer (or otherwise identified by the contractor and sanctioned in writing by the customer).

3.2 Systems Engineering Requirements

3.2.1 Requirements Analysis and Validation

The contractor **shall** perform requirements analysis and validation to develop the associated required systems engineering products with the product attributes specified in this document.

The requirements analysis and validation activity is initiated to define the requirements baseline, then continues throughout the development process to also define the allocated and design release baselines.

3.2.1.1 Required Systems Engineering Products

a. Validated, approved, and maintained requirements baseline captured in a draft System Specification, and then final System Specification, and system-level Interface Control

Documents (ICDs) or interface specifications defining all system-level requirements and constraints and their allocations to the next lower level.

b. Documented system architecture and requirements traceability.

c. Source and engineering basis including each tradeoff or other analysis for each system-level system performance and functional requirement and its allocations to the lower levels.

3.2.1.2 Required Product Attributes

a. The requirements baseline:

(1) Includes and traces to the operator/user capabilities for which the system is being designed and to the missions for which it is intended.

(2) Includes analyses of each lower-level requirement to ensure that it is valid, necessary, and current, and satisfies the higher-level capabilities, requirements, or constraints from which they resulted.

(3) Consists of verifiable requirements with the method of verification documented.

(4) Includes system interoperability needs, including any interface constraints identified in the approved concept documents and the operational and system architecture views.

(5) Includes all functional and performance requirements and constraints and those imposed by each specialty function (see Subsection 4.1).

(6) Includes all constraints, including external and internal interfaces and operating, launch, transportation, and storage environments; and design constraints for interoperability, security, safety, human factors, reliability, maintainability, and all other relevant constraint categories.

(7) Results from documented decision trade studies (tradeoffs) that balance system effectiveness, life cycle cost, schedule, risk, and the potential for evolutionary growth.

(8) Is validated through customer review and documented agreement/approval to ensure:

(a) Compliance with the above attributes.

(b) A balanced solution, including system effectiveness, life cycle cost, schedule, risk, and evolutionary growth potential issues.

(9) Is documented and controlled in a system specification and system-level ICD as applicable.

b. The system architecture and requirements traceability matrices:

(1) Provide two-way traceability between the requirements baseline and the requirements source.

(2) Trace among the architecture and system technical requirements, capabilities, and missions upward to mission and downward to functional and performance requirements at the system level.

(3) Trace from the system technical requirements to the requirements baseline and, as they are developed, the allocated, design release, and product configuration baselines.

(4) Are maintained such that changes to any requirement, capability, system, software, or physical component are identified and updated for each applicable item in the matrices.

c. The basis for each element of the requirements documentation includes:

(1) Supporting rationale for requirement statements determined from the requirements analysis, functional analysis, and design trades results and be linked to the element of the requirements baseline.

(2) Verification statement associated with each requirement and verification method of analysis, inspection, demonstration, or test.

3.2.2 Functional (Logical) Analysis

The contractor **shall** perform functional (logical) analyses, allocations/assignments, and validation iteratively based on tradeoffs to develop a functional architecture or logical representation of the system and develop the associated required systems engineering products with the product attributes specified in this document.

3.2.2.1 Required Systems Engineering Products

a. Logical solution representations (functional architectures).

b. Mission critical fault analysis (MCFA).

c. Engineering basis is documented for all functional/logical solutions.

3.2.2.2 Required Product Attributes

a. The resulting logical solution representation (functional architecture):

(1) Accurately and completely reflects the minimum or threshold required operational capabilities consistent with concepts of operation, system behavior, and required functionality.

(2) Accurately and completely reflects the functional and performance requirements in the requirements baseline.

(3) Accurately models the system behavior to include, but not be limited to, all sequencing, concurrency, and timing requirements.

(4) Includes data flow relationships that provide data associations necessary to derive requirements from the functional or logical analyses.

(5) Is sufficiently defined to form the basis for detailed and precise functions or logical elements and their allocated or derived performance/functional requirements at the next lower level.

(6) Is decomposed to lower levels to the point that each can be related to elements of the physical hierarchy to form the allocated baseline, and the allocation of the system performance requirements and design constraints to the lower levels is complete.

(7) Includes the relationships to the physical implementation and is documented in the decision database.

(8) Includes the definition of both the internal and external interfaces, and addresses the physical implementation, as well as the logical issues, such as data formats, data semantics, etc., as they apply. Uses industry standard interface technologies and protocols as applicable.

(9) Has a decision for each decomposition, grouping, sequencing, timing, iteration, and concurrency that is chosen shall be supported by documented tradeoff or other analysis.

(10) Is validated through customer involvement to ensure:

(a) Compliance with the above attributes.

(b) Two-way traceability between each element of the requirements baseline and each element of the functional architecture.

(c) Two-way traceability between each element of the functional architecture and the functional and physical elements of the system-level architectures.

(d) The assessments that all requirements can be met and are consistent with cost and schedule constraints.

b. Mission critical fault analysis (MCFA) includes:

(1) List of mission critical failures that can cause loss of mission or inability to execute mission.

(2) For each mission critical failure, the fault analysis with potential flaw contributors.

3.2.3 System Element Design Solution and Validation

The contractor **shall** determine the design solution, support validation of the design solution, and develop the associated required systems engineering products with the product attributes specified in this document.

3.2.3.1 Required Systems Engineering Products

a. The validated, approved, and maintained allocated (design-to) baseline in specifications and interface documents grouped by each system element such as segment, subsystem, component (hardware and software), computer software unit, and part.

b. Design reference timeline.

c. Engineering basis documented for all design solutions.

3.2.3.2 Required Product Attributes

a. The allocated baseline:

(1) Identifies all system products and establishes the interactions of the system.

(2) Documents the assessment of alternative solutions; identifies and quantifies decision criteria; and analyzes decision uncertainties.

(3) Includes the design-to technical functional and performance requirements and design constraints for each product.

(4) Includes all derived design-to requirements and design constraints for each product.

(5) Includes all internal and external interfaces and addresses how the interface will be implemented, including operational usage descriptions for transactions originating before and ending after a defined interface, as well as the logical issues such as data formats, data semantics, etc.

(6) Includes the verification method(s) selected for each requirement.

b. The Design Reference Timeline shall include a literal timeline or sequence of functional requirements for each mission phase.

3.2.4 Design for Implementation, Deployment, Operations, and Support

The contractor **shall** design the products that constitute the system implementation (fabrication and code) and sustainment assets, and develop the associated required systems engineering documentation with the attributes specified in this document.

3.2.4.1 Required Systems Engineering Products

a. The validated, approved, and maintained design release baseline.

b. Engineering basis documented for all design solutions.

3.2.4.2 Required Product Attributes

a. The design release baseline:

(1) Fully satisfies the allocated baseline.

(2) Identifies all additional system products necessary to manufacture, code, author, or buy; integrate; verify; deploy; train; operate; support/sustain; and dispose of the system and its constituent products over the life cycle.

(3) Is designed to implement interoperability with both internal and external interfaces for all mission phases.

(4) Systematically derives functionality from the operationally stated interoperability constraints.

(5) Integrates the functional and physical interface designs and associated functions and requirements across systems.

(6) Incorporates nondevelopmental items (NDI), commercial off-the-shelf (COTS), precedented designs, technologies at the customer-specified technology readiness level (TRL) (refer to the SMC Systems Engineering Primer and Handbook [1] for TRL descriptions) and modular, open systems approaches when such alternatives can satisfy the requirements and allocated baselines and the resulting design balances system effectiveness, life cycle cost, schedule, risk, and potential for evolutionary growth.

(7) Ensures that the reused item has been qualified in the conditions specified for the new application.

(8) Requires only part types, materials, and processes that have been fully characterized prior to their design application and/or can be fully qualified prior to use for verification, flight, or delivered product.

(9) Includes the identification of limited life products and age-sensitive materials, and the procedures for managing such products.

(10) Includes the identification of safety hazards and procedures for safe handling, storage, and operations.

(11) Is validated through customer involvement to ensure:

(a) Compliance with the above attributes.

(b) Two-way traceability between each element of the requirements baseline and each element of the functionally architecture.

(c) That assessments of the system effectiveness, life cycle cost, schedule, risk, and evolutionary growth potential show that the requirements baseline can be feasibly and affordably satisfied.

(d) That LYF tests to support design decisions are architected and designed to reflect mission usage, including appropriate selection of mission characteristics, and critical fault risk assessment for deviations from mission characteristics or usage.

b. The basis for each design selection:

(1) Is linked to the applicable element(s) in the design release baseline.

(2) Includes the source requirement in the allocated baseline and the tradeoff or other analysis.

3.2.5 Implementation

The contractor **shall** build, code, or buy the products that make up the system to include the implementation (fabrication and code) and sustainment assets.

3.2.5.1 Required Systems Engineering Products

Product configuration baseline.

3.2.5.2 Attributes

The Product Configuration Baseline:

a. Defines the system to its lowest-level components that are fabricated or coded in a manner that fully satisfies the Design Release Baseline over the system life cycle.

b. Includes all additional system products necessary to manufacture, code, author, or buy; integrate; verify; deploy; train; operate; support/sustain; and dispose of the system and its constituent products over the life cycle.

c. Is validated through customer involvement to ensure two-way traceability.

3.2.6 Integration

The contractor **shall** integrate lower-level elements (such as components, software units, configuration items, computer software configuration items, and systems) into the next higher level and develop the associated required systems engineering products with the product attributes specified in this document. Integration activities are performed with approved assembly/integration and verification procedures at each level of the buildup.

The contractor **shall** allocate LYF validation tests to appropriate levels of hardware, software, and hardware/software integration; to appropriate vendors; and to levels of mission functional integration. The customer or customer representative shall coordinate multiagency and/or multicontractor LYF integration test planning and discrepancy resolution.

3.2.6.1 Required Systems Engineering Products

a. Assembly/integration and verification procedures.

b. Discrepancy reporting, causal analysis, and corrective action procedures.

c. LYF test architecture and design plans, LYF test procedures, LYF test exceptions and associated fault risk assessment, and LYF test results and discrepancies.

3.2.6.2 Required Product Attributes

a. The documented assembly/integration and verification procedures include:

(1) Defined integration roles and responsibilities of all contractors and government participants.

(2) Assembly/integration, verification, and LYF test validation of component/software unit interfaces and mission functionality/interoperability.

(3) Assembly/integration, verification, and LYF test validation of hardware/software item interfaces and mission functionality/interoperability.

(4) Integration/verification/validation of system and support interfaces and mission functionality/interoperability.

b. Discrepancy reporting, causal analysis, and corrective action procedures are integrated with the assembly and verification procedures and LYF test validation procedures.

c. LYF test information is correlated to provide context and significance:

(1) Each test objective is mapped to mission phase objectives, first-time events, mission-critical events, and/or fault paths.

(2) Test-specific exceptions are mapped to mission characteristics and MCFA fault paths.

(3) Each test discrepancy is mapped to identified associated test exceptions or MCFA fault paths, where possible.

3.2.7 Design Solution Verification

The contractor **shall** verify the system's design and development to confirm that the system meets all documented requirements (using AIAA-S-117-2010 for space systems) and develop the associated required systems engineering products with the product attributes specified in this document.

3.2.7.1 Required Systems Engineering Products

a. Documented system verification program.

b. Verification results.

c. Design qualification data.

d. Acceptance verification data.

e. The validated, approved, and maintained product configuration baseline.

f. Mission critical fault analysis (MCFA).

3.2.7.2 Required Product Attributes

a. The system verification program:

(1) Quantitatively verifies that each system product (whether new, modified, NDI, or COTS) meets all of its allocated requirements and design constraints in accordance with the verification method for each requirement or constraint in the allocated baseline.

(2) Includes system effectiveness evaluation and manufacturing process proofing.

(3) Addresses verification requirements and criteria for solution alternatives; definition of verification to demonstrate proof of concept; and development, qualification, acceptance, pertinent operational, and other testing.

(4) Addresses life cycle requirements for test consistency in and across the solution set.

(5) Addresses the requirements and procedures needed to verify critical verification methods and processes (such as key methods, assumptions, and data used in verifications by analysis).

(6) Includes progressive verification that product and process designs satisfy their requirements (including internal and external interfaces) from the lowest level of the physical hierarchy up to the total system.

(7) Correlates identified discrepancies with respect to the product configuration baseline, technical performance metrics, and constraints.

(8) Maintains a record of all discrepancies.

b. Verification results:

(1) Verify required performance of all critical characteristics by demonstration and test. Where total verification by demonstration or test is not feasible, testing verifies key characteristics and assumptions used in the design analysis or simulation.

c. The design qualification data:

(1) Provides the verification method for each requirement in the requirements and allocated baseline and each verification requirement in the design release baseline.

(2) Confirms that the design of the system (hardware and/or software) complies with each requirement and constraint in the requirements baseline and that the design of each system product and integrated assembly of products that is separately documented in the allocated and/or design release baselines complies with each of its requirements and constraints.

(3) Confirms that each component (hardware and/or software) has adequate design margin to account for the uncertainties over the system life cycle.

(4) Is based on all applicable verification data obtained by test, demonstration, or inspection (where the verification method is by analysis), accepted values for physical constants, and, where applicable, validated threat data.

d. The acceptance verification data:

(1) Verifies that each delivered hardware product, each constituent product of a delivered hardware product, and each system product that is used to manufacture, verify, integrate, or deploy end products that are to be delivered meets each of its requirements

(other than those for which the verification method is analysis) in the maintained, allocated design release, and/or product configuration baselines in accordance with the applicable verification method or verification requirements.

(2) Confirms that each hardware component and integrated assembly has been found free of deficiencies in workmanship and materials based on the inspections and tests required by the design release baseline.

(3) Verifies that each software element and operational procedure performs the intended actions without unexpected effects and is free of detectable errors.

(4) Verifies interoperability of all elements (hardware, software, and operations).

e. The product configuration baseline:

(1) Incorporates the validated, approved, and maintained design release baseline.

(2) Is based on the planning, monitoring, decisions, and control processes.

(3) Is formed after confirmation of qualification that each product design satisfies all functional and performance requirements and constraints in the current allocated and design release baselines.

(4) Is formed after confirmation that as-built, as-coded, as-procured, or as-integrated product that has been verified for delivery acceptance as required herein is accurately reflected in the baselines.

(5) Is validated based on objective data to ensure compliance with the above attributes.

f. See Section 5.1.10 for attributes.

3.2.8 Design Solution Validation

The contractor **shall** support the government's validation of the evolving physical solution and develop the associated required systems engineering products with the product attributes specified in this document.

3.2.8.1 Required Systems Engineering Products

a. System Validation Plan

b. System Validation Data

3.2.8.2 Required Product Attributes

a. The System Validation Plan:

(1) Defines in detail and documents the validation process the contractor intends to follow pursuant to system validation to ensure that the system meets stakeholder expectations.

(2) Identifies any computers and other resources needed for such efforts as well as any needed government-furnished equipment (GFE) and government-furnished information (GFI).

(3) Documents a plan for modeling and simulation in conjunction with the validation effort, including human-in-the-loop simulation that includes:

(a) The appropriate level of detail, given the available time and other resources as well as the granularity of information available at the time.

(b) A representation of all physical devices that have been identified thus far in the synthesis step of the systems engineering process.

(4) Is refined in subsequent iterations of the design effort.

(5) Utilizes techniques, as appropriate, such as structured walk-throughs, mock-ups, simulations, and operational testing to ensure that the system, when completed, will satisfy stakeholders' requirements.

(6) Includes plans for accomplishing LYF assessments, including a mission readiness test.

b. System Validation Data:

(1) Confirms that the system (hardware and software) as built satisfies the user's needs and requirements.

(2) Confirms that the system fulfills all the required functions, and only those required functions, in an operational environment.

(3) Documents any discrepancies between the:

(a) Product configuration baseline and stakeholder expectations.

(b) Specified performance and the performance obtainable by the physical devices selected for the system or its components.

(c) The LYF test characteristics and mission characteristics.

(4) Includes inputs to the Operational Safety, Suitability, and Effectiveness/Space Flight Worthiness (OSS&E/SFW) certification, including the definition of interim and final SFW objectives based on certification criteria provided by the government and the assessment of progress to meet the criteria.

(5) Includes support to the system readiness reviews to include the mission readiness review, flight readiness review, and the postflight reviews.

(6) Supports IOT&E, including:

(a) Inclusion of developer support in the planning and execution of IOT&E, including definition and interfaces with operational test agencies.

(b) Execution of IOT&E scenarios in simulated IOT&E environments to the degree practical during DT&E.

(c) Delivery of verified technical manuals, operating procedures, and training programs (or requirements for any training not to be performed under the contract) for operational personnel prior to the start of IOT&E.

(d) Delivery of requirements for government-inventory (common) support equipment in time for its availability prior to the start of IOT&E.

(e) Deployment and readiness of verified system operational equipment (including software) and developer-supplied support equipment.

(f) Delivery of developer-supplied spares prior to the start of IOT&E.

(7) Includes LYF test results, discrepancies, and exceptions.

3.2.9 Application Across the Life Cycle

The contractor **shall** integrate its systems engineering process with the design review process specified by contract (see Table 3-1).

Table 3-1. Development Stages for Increasing Accuracy and Completeness of the Program Baselines

Technical Review or Audit		Required Maturity of the Baselines			
		Requirements	Allocated	Design Release	Product Configuration
Alternative Systems Review	ASR	Preliminary, focus on support to JCIDS	Preliminary, focus on physical elements that drive cost, risk, and other considerations	Preliminary – basis for support to capability needs process and for concept refinement	—
System Requirement Review	SRR	Draft that balances system effectiveness, cost, schedule, risk, and growth potential	Preliminary, focus on physical elements that drive risk or other considerations	Preliminary – reflects concept refinement and basis for technology maturation and other risk reduction	—
System Functional Review	SFR	Approved IAW 3.2.1	Draft that balances system effectiveness, cost, schedule, risk and growth potential	Preliminary – basis for technology selection and for the assessment to support requirements baseline validation	—
Software Requirements and Architecture Review	SAR	Review the Software Architecture and Functional Requirements Baseline IAW 3.1.2, 3.2.1, & 3.2.2	Approve the Software Architecture and Functional Requirements Baseline IAW 3.1.2 & 3.2.1–3.2.3	Approve the Software Architecture, Functional, and Design Baseline IAW 3.2.4–3.2.8	—

Technical Review or Audit		Required Maturity of the Baselines			
		Requirements	**Allocated**	**Design Release**	**Product Configuration**
Preliminary Design Review	PDR	Maintained	Approved IAW 3.2.3	Draft – basis for assessment to support allocated baseline validation	—
Critical Design Review	CDR	Maintained	Maintained	Approved IAW 3.2.4 build, buy, code, author, and integrate developmental system products for qualification	—
Functional Configuration Audit	FCA	Maintained	Maintained	Maintained	—
System Verification Review	SVR	Maintained	Maintained	Maintained	—
Physical Configuration Audit	PCA	Maintained	Maintained	—	Approved and subsequently maintained

4. Detailed Requirements

This section describes detailed systems engineering system analysis and control activities that **shall** be applied to a specific program based on the system and program requirements. Tailored program-specific requirements will be specified in the solicitations and invoked by the contract.

The System Analysis and Control activity functions as the planner, manager, judge, traffic cop, and secretary of the process. This activity identifies the work to be performed and develops schedules and costs estimates for the effort. It coordinates the other activities and ensures that all are operating from the same set of agreements and design iterations. It evaluates the outputs of the other activities and conducts independent studies to determine which of the alternate approaches is best suited to the application. It determines when results of one activity require the action of another activity and directs the action to be performed. It documents the results of analyses and studies, maintains control of the evolving configuration, and measures and reports progress [2].

The system analysis and control activity is essential to effectively perform cross functional and organizational integration and manage and control the engineering efforts. System Analysis and Control is an integral component of the systems engineering process depicted in Figures 3-1 and 3-3.

The analysis and control activity supports and complements the overall program monitoring and control activity.

4.1 System Analysis

System Analysis includes the broad range of assessments, trades, and analyses performed over the entire life cycle of a system. Contractors **shall** determine and perform system analyses as necessary to determine balanced technical solutions pertaining to system concepts, technologies, requirements, and designs of a system and its components.

The contractor **shall**:

a. Determine which analyses are required to meet contractual requirements, objectives, applicable standards, engineering practices, and data item descriptions that apply.

b. Determine and define each analysis methodology applying the attributes listed here and the specific analytical attributes and guidance provided in the subsections below.

   (1) Define the analytical tasks to be performed.

   (2) Plan analysis such that their performance is timed to provide optimal benefit to support other required analyses and trades as well as system and program design, production, and test decisions.

   (3) Retain analysis results in the decision and verification databases.

   (4) Periodically validate models used to support the analysis. Ensure that model inputs and outputs are valid and the model structure, formulations, and algorithms are correct and current.

c. Perform the analysis following the approved method or procedure.

d. Prepare the analysis report.

e. Leverage the analytical results with the other engineering and program activities.

4.1.1 Assessments of System Effectiveness, Cost, Schedule, and Risk

The contractor **shall** assess the system effectiveness, life cycle costs, schedule, risk, and evolutionary growth potential for each tradeoff following each iteration of the systems engineering process, and develop the associated required systems engineering products with the product attributes specified in this document.

4.1.1.1 Required Products

a. Documented process for assessing system effectiveness, cost, schedule, and risk.

b. Documented system effectiveness assessments and reports.

c. Documented cost assessments and reports.

d. Documented schedule assessments and reports.

e. Documented risk assessments and reports.

f. Documented critical fault risk assessments and reports.

4.1.1.2 Required Product Attributes

a. The documented process:

(1) Integrates the system/cost effectiveness analysis and assessment tasks into the systems engineering process to support development of life cycle balanced products and processes.

(2) Identifies for each assessment to be performed:

(a) The tools, source data, assumptions, methodology, and development tools/environments used.

(b) Quantified objectives and goals.

(c) Measurements, measurement objectives, and analyses activities and how they correlate with required capabilities, system technical requirements, and constraints.

(d) The elements of performance, cost, schedule, and risk that could be affected by the factors considered in each tradeoff required by the physical solution verification process.

b. Each assessment of system effectiveness:

(1) Considers parameters that encapsulate the capability needed as well as the engineering specialty functions in selecting the elements most affected by the factors considered in a tradeoff.

(2) Surfaces deficiencies for key performance parameters (KPPs) and ensures that the traceability between the MOEs, MOPs, KPPs, and TPMs is maintained.

(3) Is based on, and linked to, quantitative test, demonstration or inspection data, applicable handbook data; analysis and verification data; or OT&E data when it becomes available.

(4) Utilizes effectiveness models, including simulations, when they contribute to the decision process.

(5) Is based on prototype or developed system hardware and software embedded in the analysis when that balances cost, schedule, and risk.

(6) Compares the applicable elements of the integrated architecture for interoperability to the Defense Information Standards Registry (DISR) and all other internal/external interface issues.

(7) Includes environmental analysis and impact.

c. Each assessment of cost:

(1) Is based to the extent applicable on quantitative historical cost data.

(2) Applies a methodology that is accepted industrywide.

(3) Is based on relationships for which the assessment documentation includes the derivation when new approaches or technologies require new cost estimating relationships or procedures.

(4) Employs simulation where cost effective.

(5) Includes established design-to-cost targets, a current estimate of these costs, and known uncertainties in these costs.

(6) Addresses cost and schedule risk.

(7) Is conducted and updated as designated in the contract to support decisions, assessments of system cost effectiveness, and tradeoff studies to:

(a) Identify the sunk costs to the extent required for the specific cost assessment.

(b) Provide an estimate of the remaining development, production, operations and support (O&S), and life cycle costs for the proposed system concept to include new or modified government facilities.

(c) Demonstrate that the system concept and development plans for completing development—including any plans for new parts, materials, or processes, new or modified facilities, or other new or modified resources—are affordable and meet the program schedule requirements at acceptable risk.

(d) Identify the economic consequences of solution alternatives.

(e) Develop the requisite cost information to support decisions on alternative people, product, and process solutions and risk assessments.

d. Each assessment of schedule:

(1) Is based on quantitative historical time spans where available and applicable.

(2) Includes any necessary assumptions explicitly stated and applied so that consistency is achieved among assessments.

e. Each assessment of risk:

(1) Develops objective text descriptions identifying each risk.

(2) Identifies why and when each risk might occur.

(3) Specifies the likelihood and possible consequences.

(4) Proposes corrective actions to mitigate the risk.

(5) Develops a plan/metrics to monitor risks and corrective action plans.

f. Each assessment of critical fault risk (CFR):

(1) Includes all first-time events and mission critical activities not allocated to a LYF test as part of program test plans.

(2) Includes LYF test exceptions that are correlated to the mission critical fault analysis (MCFA).

(3) Each CFR shall be considered to be 50% probable (either potential flaw exists or not).

4.1.2 Tradeoff Analysis

The contractor **shall** identify, organize, plan, and conduct tradeoffs to compare the capability or effectiveness, life cycle cost, schedule, and risk implications of each promising alternative, and develop the associated required systems engineering products with the product attributes specified in this document.

4.1.2.1 Required System Engineering Products

a. Documented tradeoff analyses.

4.1.2.2 Required Product Attributes

a. Documented tradeoff analyses include:

(1) The objective comparative assessments of system effectiveness, life cycle cost, schedule, risk, and evolutionary growth implications for each feasible alternative requirement, functional decomposition, allocation, and/or design selection.

(2) Standards for the integrated architecture that assure interoperability.

(3) Plans and results that are documented and included in the decision database.

4.1.3 Decision Analysis

The contractor **shall** implement the actions necessary to evaluate and select from alternatives in order to develop the baselines, functional architecture, and other systems engineering products required herein to achieve approval of the baselines, and to maintain the baselines and functional architecture over the system life cycle.

4.1.3.1 Required System Engineering Products

a. Documented and implemented decisions

b. Maintained baselines and functional architecture

4.1.3.2 Required Product Attributes

a. Documented and implemented decisions are:

(1) Included in the decision database for each iteration and each design selection toward achieving the baseline attributes.

(2) Explicitly related to the tradeoffs and assessments conducted or other objective analyses or monitoring data.

(3) Captured in terms of proposed baselines or functional architecture or updates or changes thereto, corrective action plans, and/or updates to the plans and monitoring devices required above.

b. Maintained baselines and functional architecture includes:

(1) The assessment of each proposed change to a baseline or the functional architecture to determine:

(a) The corresponding impacts to the other baselines or the functional architecture.

(b) The impacts to the system effectiveness and potential for growth in relation to the requirements baseline.

(c) The impacts to both total program life cycle and instant contract cost, schedule, and risk.

(2) Relating the basis for the proposed change to these assessments to determine if the proposed change is justified.

(3) The two-way traceability from the systems engineering program foundation through the baselines and functional architecture as well as traceability from each element to the supporting analyses and assessments, and the balance between system effectiveness and evolutionary growth potential (explicitly) to avoid the potential for significant added cost, schedule, or risk for small gains in effectiveness.

(4) Documentation of the basis, assessments, justification, agreements, and approvals for each change in the decision database.

(5) The status of the implementation of all approved changes in affected system and systems engineering products.

4.1.4 Operational Analysis and Assessment

The contractor **shall** conduct operational analyses and assessments to support the development of people, product, and process solutions necessary to satisfy operational requirements for system end items.

4.1.4.1 Required System Engineering Products

Operational analysis-related tradeoffs and analyses linked to the system engineering process iterations of which they are a part and to any decisions that they support or justify.

4.1.4.2 Required Product Attributes

a. Analyses and assessments of the operational use of alternative solutions addressing:

(1) How solutions will be used to accomplish required tasks in their intended environments.

(2) Interfacing systems required to execute operational functions in the intended use environment.

(3) Joint and combined operations.

(4) Modes of operational deployment, mission phases, and mission employment.

b. Includes mission operations-critical characteristics of people, product, and process solutions and their risks mission, including those derived from mission critical flaws, in the risk management process.

4.1.5 Environmental Analysis and Impact Assessment

Environmental analysis **shall** be performed to determine the impact on and by each system product and process alternative.

4.1.5.1 Required System Engineering Products

Environmental-related tradeoffs and analyses linked to the system engineering process iterations of which they are a part and to any decisions that they support or justify.

4.1.5.2 Required Product Attributes

a. Adheres to all applicable statutes and to contractually designated hazardous materials lists.

b. Analyzes factors such as noise pollution, quantities, and types of hazardous materials used, hazardous waste disposal, and other defined environmental requirements as applicable.

c. Defines and assesses methods to mitigate problems and impacts identified from this analysis.

d. Includes the results of these assessments into effectiveness analyses as well as system definition, design, and verifications.

e. Documents analysis output appropriate to the acquisition phase and use in conjunction with cost and performance analyses outputs to support acquisition phase exit criteria.

f. Avoids use of materials that present a known hazard to the environmental.

g. Includes environment-critical characteristics of people, product, and process solutions, and their risks included in risk management process.

4.1.6 Training Analysis and Assessment

The contractor **shall** conduct training analyses and assessments to support development of people, product, and process solutions to train users of system end items.

4.1.6.1 Required System Engineering Products

Training-related tradeoffs and analyses linked to the System Engineering Process iterations of which they are a part and to any decisions that they support or justify.

4.1.6.2 Required Product Attributes

a. Includes the development of personnel capabilities and proficiencies to accomplish tasks at any point in the system life cycle to the level they are tasked.

b. Considers both initial and follow-on training necessary to execute required tasks associated with system end-item use.

c. Includes training-critical characteristics of people, product, and process solutions and their risks in risk management process.

4.1.7 Transition (Deployment) Analysis and Assessment

The contractor **shall** conduct deployment analyses and assessments to support the development of people, product, and process solutions necessary to deploy system end items and develop the associated required systems engineering products with the product attributes specified in this document.

4.1.7.1 Required System Engineering Products

a. Tradeoffs and other analyses that are linked in the decision database to the System Engineering Process iterations of which they are a part and to any decisions that they support or justify.

4.1.7.2 Required Product Attributes

a. Deployment analyses and assessments address:

(1) Factors for site/host selection, activation/installation, field assembly, and checkout requirements, including identification of site-unique hazard classification and explosive ordnance disposal requirements.

(2) Operational and maintenance facilities and equipment requirements.

(3) Compatibility with existing infrastructure (e.g., computer/communication systems).

(4) Determination of environmental impacts and constraints (environment impacts on the system and system impacts on the environment) at deployment sites as defined by the environmental analysis and impact assessment task.

(5) Training items and personnel.

(6) Provisioning and spares.

(7) Packaging, handling, storage, and transportation.

(8) Site transition requirements.

(9) Deployment-critical characteristics of people, product, and process solutions to be included in risk management efforts.

4.1.8 Supportability Analysis and Assessment

The contractor **shall** conduct supportability analyses and assessments to assist in the development of people, product, and process solutions to support system end items over the system life cycle.

4.1.8.1 Required System Engineering Products

Supportability-related tradeoffs and analyses linked to the System Engineering Process iterations of which they are a part and to any decisions that they support or justify.

4.1.8.2 Required Product Attributes

a. Identifies all contractually specified levels of operation, maintenance, and training for system end items.

b. Identifies and integrates into the SE process supportability-related factors to ensure that system end items satisfy their intended uses.

c. Develops a complete and integrated support structure (people, products, and processes) across the system life cycle.

d. Specifies support resource needs, including parts, people, facilities, and materials.

e. Includes supportability-critical characteristics of people, product, and process solutions and their risks included in the risk management process.

4.1.9 Disposal Analysis and Assessment

The contractor **shall** conduct disposal analyses and assessments to support development of people, product, and process solutions to dispose of products and by-products.

4.1.9.1 Required System Engineering Products

Disposal-related tradeoffs and other analyses to the System Engineering Process iterations of which they are a part and to any decisions that they support or justify.

4.1.9.2 Required Product Attributes

a. Identifies environmental factors for process waste and output as well as used products and components.

b. Evaluates effective disposal methods for system parts and materials and requirements for new or modified methods, including storage, dismantling, demilitarization, reusing, recycling, and destruction.

c. Identifies costs, sites, responsible agencies, handling and shipping, supporting items, and applicable federal, state, local, and host nation regulations as factors.

d. Includes disposal-critical characteristics of people, product, and process solutions and their risks in the risk management process.

4.1.10 Mission Critical Fault Analysis (MCFA)

The contractor **shall** conduct a mission critical fault analysis to identify the mission critical failures for each mission phase and the fault conditions that led to each failure.

4.1.10.1 Required System Engineering Products

a. Mission critical fault analysis

4.1.10.2 Required System Engineering Attributes

a. Mission failures are identified by a team representing all mission elements and technical disciplines.

   (1) Each potential mission failure will be populated with all single fault paths to that failure.

      (a) Single fault paths include those that involve mismatches between two items or elements (e.g., race conditions, counting strategy, or engineering units).

b. Each mission failure analysis will be documented (e.g., in an analytical tool such as master logic diagram, fault tree, event tree, or Ishikawa diagram).

c. MCFA will be updated as necessary to reflect changes in operations, hardware design, or software design.

4.2 Systems Control

4.2.1 Management and Control of the Systems Engineering Process

The contractor **shall** plan, execute, and control the engineering efforts. In addition, the contractor **shall** ensure appropriate flowdown of requirements and technical management of subcontractors and vendors.

Typical control activities are illustrated in Figure 4-1. The control activities are executed according to the planning and include monitoring (measurements/metrics programs, technical reviews and audits, corrective action programs), interface management/control, risk management, configuration management, data management, decisionmaking, architecture management, and requirements management.

4.2.1.1 Planning

The contractor **shall** plan all aspects of the systems engineering effort.

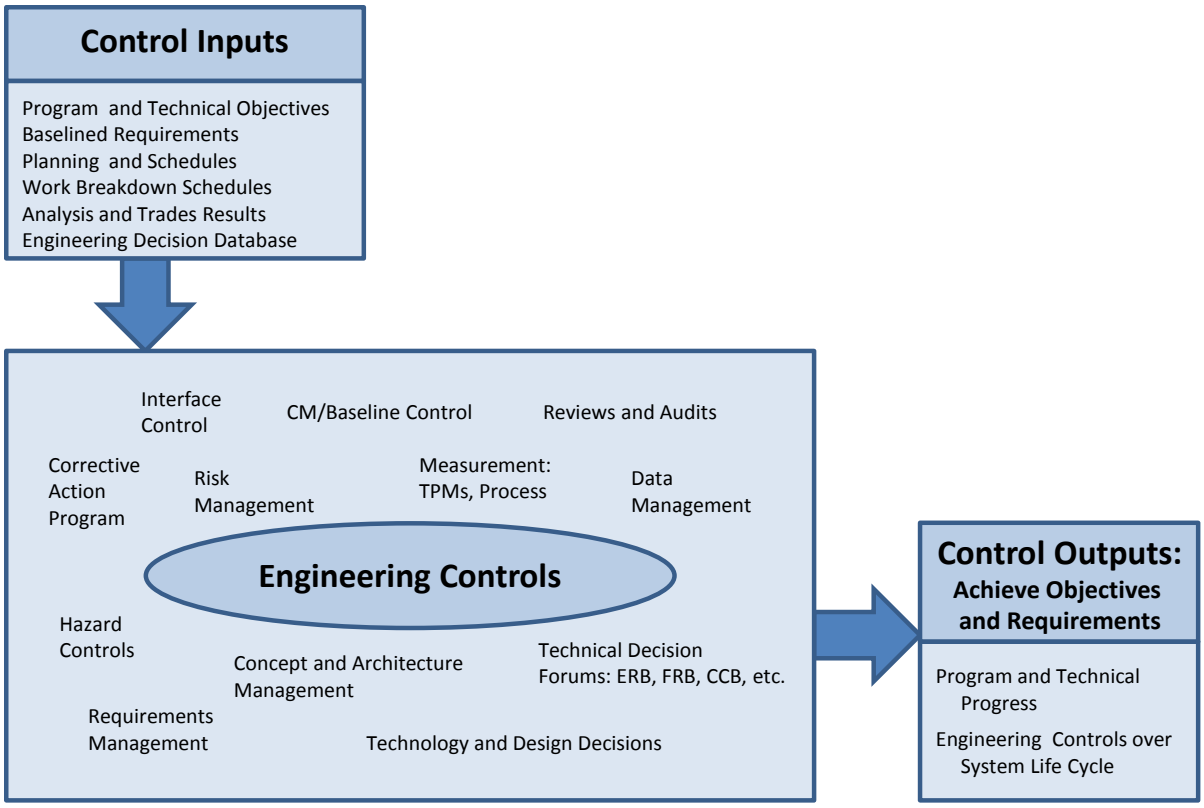

Figure 4-1. Engineering control activities.

4.2.1.1.1 Required System Engineering Products

a. Contract Work Breakdown Structure (CWBS)

b. The systems engineering accomplishments, accomplishment criteria, and narrative in the integrated master plan (IMP); tasks in the integrated master schedule (IMS); and work packages in the earned value management system (EVMS), and other specific plans (such as tradeoff plans) as may be needed to achieve the attributes required above.

4.2.1.1.2 Required Product Attributes

a. The CWBS is consistent with the evolving physical hierarchy and is maintained and applied to plan and monitor all work carried out under the contract.

b. The IMP, IMS, EVMS, and other specific plans as needed:

(1) Reflect all technical execution and management efforts.

(2) Are organized to support orderly decisionmaking (such as in a decision tree).

(3) Establish schedules consistent with all other program plans for the completion of TBDs, formalization of TBSs, or resolution of TBRs in approved baselines.

4.2.1.2 Monitoring

The contractor **shall** monitor the progress against all planning to:

a. Identify decisions that are initially necessary to provide the minimum capabilities needed and to satisfy the requirements baseline.

b. Validate, approve, and maintain each baseline and the functional architecture.

c. Maintain the design balanced with respect to system effectiveness, cost, schedule, risk, and potential for evolutionary growth.

d. Monitor/mitigate each risk.

4.2.1.2.1 Required System Engineering Products

a. Comparison of all systems engineering assessments in the decision database to the initial plans, the results of each iteration for which it is a part to include tradeoffs and other assessments, the decisions made and their justification, and the actions taken.

4.2.1.2.2 Required Product Attributes

a. Each documented assessment includes, but is not limited to:

(1) Status of system effectiveness, schedule, life cycle cost, risk (to include the status of the risks on the watch list), including progress against the plans.

(2) Assessments of the verification and validation data (when developed products are available) to ensure effective identification, disposition, and control of deficiencies and nonconformances.

(3) Assessments of change control implementation to identify instances when baselines are not in consonance or when baselines or products are not in compliance with the change control actions.

(4) All risks, including those identified by the assessments, which are designated to be monitored as part or all of the selected mitigation approach.

(5) The TPMs, metrics, and/or renewed risk assessments for monitoring each risk.

(6) Metrics and select technical parameters for tracking that are critical indicators of technical progress and achievement and include system parameters, configuration item (CI) parameters, or both.

(7) The critical fault risk list:

(a) Includes critical fault risks associated with decisions to not perform LYF tests and with LYF test exception faults that cannot be mitigated within resources allocated to for test/repair/rework/retest.

(b) Elevates to program risk management any LYF test necessary to validate the executability of a first-time event, mission critical activity, or mission sequence that cannot be performed within element test resources.

4.2.1.3 Interface Management

The contractor **shall** manage the internal interfaces within their contractual responsibility, support activities established to ensure that external interfaces are managed and controlled, and develop the associated required systems engineering products with the product attributes specified in this document.

4.2.1.3.1 Required System Engineering Products

a. Interface definition documentation.

b. Operational concepts documentations.

4.2.1.3.2 Required Product Attributes

a. The interface definition documentation, for each system engineering iteration:

(1) Establishes, coordinates, and maintains interface controls for interface requirements, documents, and drawings, and includes all applicable contractor, vendor, and subcontractor contract items and government-furnished equipment, computer programs, facilities, and data.

(2) Controls interfaces to ensure accountability and timely dissemination of changes.

(3) Captures all changes to the internal and external interfaces in the decision database.

(4) Ensures that all interface requirements are verified.

b. The operational concepts documentation, for each systems engineering iteration:

(1) Establishes, coordinates, and maintains planned methodologies for executing each mission phase and constituent activities; interactions and transactions between operational elements; constraints and considerations for the execution of all mission activities.

(2) Controls operational and data interactions and transactions to ensure accountability and timely dissemination of changes.

(3) Captures in the decision database all changes to the constraints and considerations documented for mission operational data interactions and transactions.

(4) Ensures that all mission operational data interactions and transactions are validated in LYF tests.

4.2.1.4 Risk Management

The contractor **shall** establish and implement a risk management program and develop the associated required systems engineering products with the product attributes specified in this document.

4.2.1.4.1 Required Products

a. Risk Management Plan.

b. Risk Watch List.

4.2.1.4.1.1 Required Product Attributes

a. The Risk Management Plan:

(1) Specifies a process that documents risks (including all associated assumptions), evaluates mitigation approaches, and assesses, monitors, and documents risks associated with system requirements.

(2) Includes program risk assessment as it applies to identifying, analyzing, and ranking risks associated with system requirements for completeness and adequacy.

(3) Assesses products, processes (e.g., process variability), and their interrelationships.

(4) Includes risks associated with contractually identified variations, uncertainties, and evolutions in system environments.

(5) Identifies potential sources of technical risk, including critical parameters that can be risk drivers.

(6) Quantifies risks, including risk levels, in terms of the likelihood of occurrence and the severity of their impacts on cost (including life cycle costs), schedule, and performance. Includes design, cost, and schedule uncertainties and sensitivity to program, product, and process assumptions.

(7) Includes the activities and criteria for identifying, assessing, validating, and transitioning critical technologies from technology development and demonstration programs, including commercially developed technologies.

(8) Includes technology readiness level (TRL) in performance, affordability, and life cycle processes in the criteria.

(9) Addresses how technology refresh will be accomplished.

(10) Defines sensitivity of interrelated risks.

(11) Includes alternative approaches to handle moderate and high risks.

(12) Documents actions to avoid, control, or assume each risk.

(13) Includes an established process for continued identification of risks throughout the program life cycle.

(14) Includes the evaluation of risk factors as a part of decisionmaking, including the selection of specification requirements, and design and solution alternatives.

b. The Risk Watch List:

(1) Includes all risks, including those identified by assessments that are designated to be monitored as part or all of the selected mitigation approach.

(2) Identifies the technical performance measures (TPMs), metrics, and/or renewed risk assessments for monitoring each risk, describe the methodology, tools, and schedule for assessing each, and links each to the CWBS entry for the applicable product.

(3) Is assessed for each integrated assessment and at other times called for by the planning required to provide timely alerts of the need for risk mitigation actions.

4.2.1.5 Configuration Management

The contractor **shall**, consistent with other configuration management requirements of the contract, manage the changes to and maintain the baselines and functional architecture over the life cycle of the system, and develop the associated required systems engineering products with the product attributes specified in this document.

4.2.1.5.1 Required System Engineering Products

a. Documentation of configuration management process.

b. Assessments of change control implementation.

4.2.1.5.2 Required Product Attributes

a. The documented configuration management process:

(1) Is based on a current and active government or industry standard, or other specified by contract.

(2) Provides total life cycle configuration management planning for the program and manages the implementation of that planning.

(3) Includes configuration identification, which includes establishment of a structure for products and product configuration.

(4) Includes configuration change control, which ensures that changes to a configuration baseline are properly identified, recorded, evaluated, approved or disapproved, and incorporated and verified, as appropriate.

(5) Includes configuration status accounting, which manages the capture and maintenance of product configuration information necessary to account for the configuration of a product throughout the product life cycle.

(6) Includes configuration verification and audit, which establishes that the performance and functional requirements defined in the product definition information have been achieved by the design and that the design has been accurately documented in the product definition information.

b. Assessments of change control implementation:

(1) Include the decisions and change control actions to develop the baselines and the functional architecture.

(2) Include configuration control, including the systematic proposal, justification, evaluation, coordination, approval, or disapproval of all proposed changes to the baselines and functional architecture.

(3) Explicitly assess each proposed change to a baseline or functional architecture to determine:

(a) The corresponding impacts to the other baselines and the functional architecture.

(b) The impacts to the system effectiveness and potential for growth in relation to the requirements baseline or the needed capability and in relation to both total program and instant contract cost, schedule, and risk.

(4) Assess risks for products, processes (e.g., process variability), and their interrelationships, including contractually identified variations, uncertainties, and evolutions in system environments.

(5) Plan and conduct new verifications, and record the results in the decision database.

(6) Document the basis, assessments, justification, agreements, and approvals for each change in the decision database.

(7) Monitor the status of implementing all approved changes.

4.2.1.6 Data Management

The contractor **shall** establish and maintain a data management system, and develop the associated required systems engineering products with the product attributes specified in this document.

4.2.1.6.1 Required System Engineering Products

a. Data products as required by the contract and to support the program.

4.2.1.6.2 Required Product Attributes

a. The data products:

(1) Capture and organize all inputs as well as current, intermediate, and final outputs.

(2) Provide traceability and correlation (relationship) of data between requirements, designs, solutions, decisions, and rationale.

(3) Document engineering decisions, including procedures, methods, results, and analyses.

(4) Are responsive to established configuration management procedure.

(5) Function as a reference and support tool for the systems engineering effort.

4.2.1.7 Technical Management of Subcontractors/Vendors

The developer **shall** flow the systems engineering requirements defined herein as tailored per contract as well as the applicable technical requirements in the allocated baseline, down to any subcontractor or supplier who will conduct development tasks under the contract or subcontract, and develop the associated required systems engineering products with the product attributes specified in this document.

The developer **shall** establish effective subcontractor/vendor contracts, monitor, make decisions regarding, and control subcontractor activity to comply with the requirements herein with the same vigor and effectiveness as for activity within the developer's company.

4.3 Specialty Engineering Analysis and Control Contributions

The contractor **shall**, for each specialty area listed below:

a. Ensure that the following specialty functions and disciplines are incorporated into the systems engineering process.

b. Establish a documented valid/approved process (including but not limited to applicable corporate process, military standards, military handbooks, NSS/industry standard processes) that is comprehensive and responsive to the system/end-user requirements for each specialty engineering area being integrated into the systems engineering effort.

c. Include specialty engineering requirements in the requirements analysis, functional analysis/allocation, synthesis, and systems analysis and control.

d. Include their impact in system life cycle cost estimates as well as in total system performance/reliability assessments.

4.3.1 Parts, Materials, and Processes (PMP)

a. Detailed environmental parameters are defined/derived that impact parts performance.

b. Parts/materials engineering/design requirements are allocated, baselined, and traced to system-level performance requirements, including risk assessments.

c. Functional parameters are baselined and captured in detailed technical/procurement specifications.

d. Technology development plans are executed and technology readiness levels demonstrate products/technology suitable for system application and support program development schedules.

e. Qualified sources of supply and industrial base assessment are addressed.

f. Space systems radiation-hardening design solutions are established.

4.3.2 Structures

a. Detailed performance and technical requirements for each structural system, subsystem, and component are defined, allocated, and traced to system requirements.

b. Structural design specifications comply with requirements and NSS industry practice.

c. Verification methods for each structural requirement are defined.

d. Structural requirements correlation with military and other government documents, including standards, specifications, handbooks, guidelines, and Commander's policies, are presented.

e. Technical risk mitigation approaches are defined.

f. Trade studies and detailed analyses support structural design solutions.

g. Analysis tools and techniques are consistent with NSS industry practice.

h. Design qualification methods adequately define approach to demonstrate structural adequacy.

i. Quality assurance methodology ensures delivery of high-quality product.

4.3.3 Manufacturing

a. Producibility engineering principles and practices are integrated into the design process.

b. Manufacturing methods and processes required to build the design are qualified and demonstrated to meet system performance requirements and reliability.

c. Manufacturing analyses include producibility analyses and manufacturing and production inputs to system effectiveness, tradeoff studies, and life cycle cost analyses.

d. Alternative designs and capabilities of manufacturing are evaluated.

e. Long-lead-time items, material source limitations, availability of materials and manufacturing resources, and production cost are identified, assessed, and documented.

f. Manufacturing-critical characteristics of people, product, and process solutions and their risks are identified.

g. Tooling and test equipment strategies and requirements are defined.

h. Manufacturing and producibility requirements and constraints are defined.

i. Items are producible and stable manufacturing processes are in place to reduce risk, manufacturing cost, lead time, and cycle time, and to minimize use of strategic and critical materials.

j. As part of system design, manufacturing methods, processes, and process controls have been defined, evaluated, and selected, based on total system cost, schedule, performance, and risk.

k. Product design has stabilized, the manufacturing processes and process controls have been proven, and production facilities, equipment, capability, and capacity are in place (or are about to be established) to support the approved schedule.

4.3.4 Quality Assurance

a. Qualified inspection/test processes demonstrating effectiveness.

b. Capable processes are established for:

(1) Monitoring and control of critical processes and product variation.

(2) Establishment of mechanisms for feedback of field performance.

(3) Implementation of an effective root-cause analysis and corrective action system; continuous process improvement.

(4) Disciplined control over the design, procurement, manufacturing, integration, and test processes.

c. Quality assurance schedules are established to concurrently support procurement, manufacturing, integration, and test processes.

d. Quality assurance policies and procedures are in place to manage internal and external production sources.

4.3.5 Test

a. Design test requirements are defined, allocated, and traced to system-level requirements, including risk assessments.

b. Integrated test plans, procedures, and schedules are defined and are consistent with and integrated with program schedules.

c. All system components (hardware, software, and human interfaces) critical to verifying achievement/demonstration of system technology requirement are addressed.

d. Test tools, test equipment (including special test equipment)/software, diagnostics software, modeling and simulation requirements are defined, allocated, and traced to system components.

e. Test and verification methodologies and criteria for data gathering, reduction, and analysis are defined and documented.

f. Data acquisition requirements, documentation, methods of analysis, and pass-fail criteria are defined and documented.

g. Training and certification requirements are identified and programmed to meet test and evaluation schedules.

h. An approach to provide test support and documentation to design changes on hardware and software is developed.

4.3.6 Survivability

a. System-level survivability requirements are defined, allocated, baselined, and traced to the system-level requirements.

b. System survivability attributes and mission objectives evolved into a set of system-level survivability requirements.

c. An approach for verification of system-level survivability/operability requirements is identified.

d. Test facilities capable of simulating threat environments are identified.

e. Threat assessments and analysis are conducted, defining categories of the expected threats (i.e., nuclear, biological, terrorism, etc.) and their likelihood of occurrence.

f. Threats and mitigation strategies are defined.

g. Nuclear and other threats are translated into system environments and modeled.

h. System/threat interaction analysis is performed.

i. Hardness levels and definition of hardness margins and design criteria are identified.

4.3.7 Environmental, Safety, and Occupational Health (ESOH)

a. System-level ESOH requirements are defined, allocated, baselined, and traced to the system-level requirements:

(1) Hazards are identified.

(2) Hazardous materials are analyzed, including handling and disposal.

(3) Mitigation decisions are evaluated.

(4) Residual risk acceptance is evaluated.

(5) Current mitigation efforts are assessed.

(6) National Environmental Policy Act (NEPA) and Programmatic Environmental, Safety, and Health Evaluation (PESHE) requirements are incorporated.

b. ESOH risks and corrective actions and alternatives are developed to eliminate or reduce environmental, health, and identified hazards and unsafe conditions; and the threat of regulatory violations is identified.

c. Criteria are established for monitoring and reporting of pollution elimination/reduction efforts.

d. A containment program is developed, including procedures for safe use and disposal.

e. Handling and disposal of hazardous material are included in life cycle cost estimates.

4.3.8 Contamination

a. Requirements for contamination control are identified for sensitive components or subsystems, including:

(1) Need for normal, medium, or challenging/stressing contamination control to meet requirements.

(2) Any needs for new or upgraded facilities.

(3) Shipping and prelaunch operations.

b. Cleanliness challenges are identified and solutions proposed, including:

(1) Uncleanable materials.

(2) Solvent incompatibility.

(3) Mission-unique requirements to launch vehicle.

(4) High outgassing materials.

c. Heritage analysis comprehensively and completely demonstrates that prelaunch cleanliness requirements can be met and that overall end-of-life (EOL) requirements can be met.

4.3.9 Mass Properties

a. Mass properties requirements are reviewed and generated; changes are proposed where applicable.

b. Baselined design is reflected in the mass properties analyses and reports.

c. Subsystem and subcontractor's definition of critical mass properties parameters are reviewed and tracked to ensure that specification requirements are met.

d. Configuration layout for optimizing mass properties (weight, balance, and inertia) is analyzed.

e. Balance weight locations are defined. Provisions for balance weight installation are ensured.

f. Test plan and test procedure are generated; method of verifying requirements is defined; required mechanical ground support equipment (MGSE) is identified.

4.3.10 Logistics

a. Logistics requirements are defined, allocated, baselined, and traced to system requirements. Logistics management information (LMI), life cycle cost (LCC) analysis with a discussion of risks, and any risk reduction or control are included for the following logistics areas:

(1) Design interface – system reliability, maintainability, availability, survivability, including hardness and unique characteristics.

(2) Support concepts/maintenance plan – initial and steady-state support; implementation and transition schedule at organizational and depot level; warranties and SORAP.

(3) Manpower and personnel – operations, maintenance (hardware and software), and training support personnel.

(4) Supply support – support concept for initial and steady state, sparing requirement to support concept of operation.

(5) Support equipment and simulators – common and specialized organizational and depot support equipment, and system-level simulators and trainers.

(6) Training and training support – initial and follow-on training, equipment, documentation and facilities; student requirements.

(7) Technical data – engineering drawings and technical orders; data rights, technical manual contract/delivery requirements.

(8) Computer resource support – software and database maintenance, facilities, equipment, COTS, and documentation.

(9) Facilities – Space projections, new or reuse requirements, site survey, deployment transportable facilities.

(10) Packaging, handling, storage and transportation (PHS&T) – LMI packaging analysis, government and commercial packaging requirements, and packing requirement meet all concept of operations, including deployment storage, oversized and special packaging instruction, air, ground, or sea shipping requirements.

4.3.11 Human Systems Integration (HSI)

Note: This section presents requirements for the systems engineering planning activities associated with human systems integration. The requirements for the subordinate domains are contained within specific domain-level standards.

4.3.11.1 Scope and Nature of Work

Human systems integration (HSI) shall be applied as part of the overall systems engineering effort to efficiently and effectively integrate humans into the design of the system. The goals of the human systems integration effort **shall** be to:

a. Plan and execute efficient development of systems that effectively integrates human operators, maintainers, support personnel, and/or users.

b. Plan for impacts of military system operation, use, or disposal on potentially affected general populations.

c. Ensure system performance by ensuring human integration and specified levels of performance.

d. Apply to all aspects of military systems, equipment, and facilities acquisition, including analysis, design, development, acquisition, test and evaluation, sustainment, and product improvement.

e. Implement by making effective demands upon, and tradeoffs between, personnel resources, skills, and training to allow for knowledgeable management of total system ownership costs.

4.3.11.2 HSI Planning

HSI **shall** be part of the overall systems engineering effort within the total project and **shall** coordinate with all appropriate systems engineering specialties or disciplines.[1]

a. HSI planning **shall** establish the collaboration between HSI domain disciplines with emphasis on each domain area's participation in system (hardware and software) design and testing.

b. HSI **shall** be documented and managed accordingly.

c. Risk management — HSI-related risks and issues that involve technical, cost, or schedule risks **shall** be identified and managed as early as possible as part of a program's overall risk management approach.

d. Reviews — HSI-related activities **shall** be reported in all appropriate programmatic or technical reviews.

The contractor **shall** establish a comprehensive Human Systems Integration (HSI) effort as part of the overall systems engineering effort.

[1] Support material for HSI planning can be found in The Aerospace Corporation report TOR-2012(8960)-1 REV A – HSI Planning Requirements.

a. HSI **shall** address the following discipline areas[2]:

(1) Manpower – number and mix (military, contractor, and civilian) of personnel required, authorized, and available to train, operate, maintain, and support the system.

(2) Personnel – human aptitudes, skills, experience levels, and abilities required to operate, maintain, and support the system when fielded and throughout its life cycle.

(3) Training – instruction and resources required to provide the necessary knowledge, skills, and abilities to properly integrate, operate, maintain, and support the system.

(4) Human factors engineering – integration of human capabilities (cognitive, physical, sensory, and team dynamics) into system design, development, modification, and evaluation to optimize human-machine interactive performance for operation and maintenance of the system.

(5) Environment – issues related to water, air, and land and the interrelationships between these and all living things.

(6) Safety – issues including design of operational systems to minimize the possibilities for accidents or mishaps that threaten the survival of the system.

(7) Occupational health – minimizing risk of injury, acute and/or chronic illness, disability, and/or reduced job performance to personnel who operate, maintain, or support the system.

(8) Survivability – minimizing risk of fratricide, detection, and probability of being attacked; and inclusion of factors that enable the crew to withstand man-made or natural hostile environments without aborting mission or suffering acute/chronic illness or death.

(9) Habitability – living or working conditions necessary to sustain the morale, safety, health, and comfort of the user/maintainer population, contributing directly to personnel effectiveness and mission accomplishment.

The HSI activities **shall** be integrated into the overall systems engineering program and management. The HSI requirements specified herein shall be coordinated with, but shall not duplicate, efforts performed to fulfill other contractual program tasks. The HSI-related portion of any analysis, design, or test and evaluation program shall be conducted under the direct cognizance of a qualified HSI-domain practitioner(s) assigned such responsibility by the contractor. "Qualified" should consider basis of education, experience, and/or certification in systems engineering, human systems integration, or any of the individual HSI domains.

a. The contractor **shall** determine the scope and nature of HSI domain area applicability such that:

(1) Program/contract requirements are allocated to the appropriate HSI domain (discipline) areas.

[2] Individual DOD services/components may organize these same domain areas into different domain area combinations.

(2) Responsible entities (e.g., HSI Working Group and/or Integrated or Cross Product Teams – IPTs) are identified for each applicable HSI domain within the systems engineering IPT structure.

(3) Key or lead HSI personnel in all applicable domains are identified and described in terms of qualifications.

(4) Interfaces between related HSI domains are defined and developed to ensure comprehensive and effective execution of human-related requirements.

(5) Interfaces are established between the prime contractor and all subcontract or vendor HSI activities.

(6) Domain interdependencies and tradeoffs are identified to ensure humans are considered as part of system design on par with the hardware and software.

b. HSI planning **shall** be described in a configuration-managed document that is used to execute the HSI effort.

c. HSI planning **shall**:

(1) Include the human-related tasks to be performed, milestones, level of effort, methods, and design concepts to be used, and the test and applicable evaluation methodologies.

(2) Describe data flow between HSI domains and/or IPTs (see Appendix B Giver-Receiver relationships).

(3) Be documented as a human systems integration plan and/or within the Systems Engineering Management Plan (SEMP).

(4) Be validated/updated prior to major programmatic and technical reviews.

(5) Be updated at program rebaseline and/or engineering change proposal (ECP).

d. The following activities **shall** be considered:

(1) Integration of relevant human-related data and analyses into all design and development activities with human-related requirements, design features, or implications, especially considering the relationships between these efforts and opportunities to effect efficiencies in system development, operation, and maintenance.

(2) HSI implications for integrated development of logistics and operational support materials, including procedures, manuals, and technical documentation.

(3) User involvement and community review of human-related activities and products, including prototype assessments, peer reviews, and formal reviews.

(4) Verification and/or validation of human requirements and human-related design options/solutions.

The contractor **shall** identify and manage human-related risks, issues, and opportunities in a way that:

a. Ensures HSI-related risks are managed within the program's risk management process.

b. Identifies potential cost, schedule, technical, and performance risks that result from human system integration.

c. Quantifies such risks and their impacts on cost, schedule, and performance.

d. Evaluates and defines the sensitivity of HSI-related risks.

e. Identifies alternative solutions to HSI-related problems and defines the associated risks of each alternative.

f. Documents the identified risks, their potential impact, and the mitigation action(s) taken.

g. Manages the actions required to avoid, minimize, control, or accept each HSI-related risk.

Human systems integration domain activities **shall** be addressed in all applicable programmatic and technical reviews, including but not limited to:

a. Programmatic reviews, which include but are not limited to program management review, integrated baseline review, and integrated system review.

b. System reviews, which include, but are not limited to:

    (1) Concept and requirements definition.

    (2) Analysis of alternatives.

    (3) System requirements review.

    (4) Preliminary design review.

    (5) Critical design review.

    (6) Test readiness reviews.

    (7) System safety reviews.

    (8) Engineering change proposal reviews.

    (9) Post-implementation reviews.

c. Subsystem and other lower-level reviews including, where applicable, software specification, test readiness, and functional reviews (e.g., support, training, systems engineering, test, and manufacturing).

4.3.12 System Security and Information Assurance

a. A system security program is implemented that includes Information Systems Security Engineering (ISSE).

b. Protection needs are documented, including identification of mission assets and assessment of threats to those assets.

c. System security requirements are defined and complete. Includes system-specific threats and compliance with applicable DOD, national, and international system security policies. Includes system security design constraints.

d. System security architecture and management plan is documented.

e. Security design, including constraints and tradeoffs, is detailed; cryptography plans are coordinated with the National Security Agency.

f. Certification and accreditation process activities are coordinated.

g. Protection mechanisms have been verified to satisfy security requirements and residual security risks have been approved by the appropriate authorities.

4.3.13 Reliability

a. Space system-specific reliability requirements are defined, allocated, baselined, and traceable to system requirements.

   (1) Parameters and limits are defined at this level and provided within the system specification.

   (2) Reliability requirements are reviewed against functional requirements and customary design practices.

b. Applicable specific design tasks and analyses are conducted, including:

   (1) Failure Reporting Analysis, Corrective Action System (FRACAS).

   (2) Source selection and vendor control procedures.

   (3) Failure Modes Effects and Criticality Analysis (FMECA).

   (4) Derating and margins of safety.

   (5) Fault coverage.

   (6) Single-point failure.

   (7) Redundancy/single string.

c. The reliability program plan and risk management plan are developed for final top-level space system.

d. Items in development that have impact on support resources are identified, including time, people, money, parts, tools, storage, and transportation assets.

4.3.14 Electromagnetic Interference and Compatibility (EMI/EMC)

a. EMI/EMC requirements are defined, allocated, baselined, and traced to system requirements, including:

(1) Use of RF shielded enclosures for vehicle, subsystems, or components, and other significant design features affecting EMC.

(2) Structure RF shielding effectiveness in excess of 40 dB.

(3) Return of power on spacecraft structure.

(4) Unshielded or untwisted or unpaired wires.

(5) Radiated emissions requirements less than 20 dBuV/m.

(6) Gimbals that form part of a shielded enclosure—high risk.

(7) Radiated susceptibility requirements in excess of 100 V/m—high risk.

(8) Systems having passive intermodulation products of order 7 or less in platform receiver pass bands.

(9) Any EMC wire shields or grounds that are required to flex or rotate or rub/roll more than 20 times.

(10) Magnetic dipole requirements more stringent than 3.5E-3 A-m^2/kg.

(11) All first-flight/first-use EMC parts.

(12) All cryo-cooled sensor EMC designs.

(13) All EMC requirements with negative margin.

(14) Any RF receiver required to work in a dense EMI environment.

(15) Any RF receiver with a burnout level of less than 30 dBm (1 mW).

b. A summary of all significant areas are addressed in the EMC Control Plan, including but not limited to program requirements tailoring and the use of heritage equipment and other NDI.

c. EMC requirements verification planning to the unit level is conducted.

d. EMI/EMC risk areas are identified and risk mitigation closure plans developed.

4.3.15 System Safety

a. System safety requirements are defined, allocated, baselined, and traced to system requirements, including:

   (1) System safety design requirements are specified and safety design criteria determined.

   (2) Hazards associated with the system are identified and risks involved identified; hazard analysis is complete.

   (3) Risks are minimized in the design, materials, testing, and production of end item.

   (4) Retrofit actions are minimized by inclusion of safety features during definition and development of system.

   (5) Retrofit actions are minimized by inclusion of safety features during definition and development of system.

b. Hazardous substances, components, and operations are isolated from other activities, areas, personnel, and incompatible materials.

c. Catastrophic risks are eliminated.

d. Critical hazards are minimized.

5. Notes

5.1 Intended Use

This section contains information for reference only.

The primary purpose of this document is to be specified by the government on space system development contracts as a compliance document. Therefore, the requirements herein are intended to be contractor requirements. This document, however, can be used by the government as a guide to assist in systems engineering planning in terms of the required systems engineering efforts. Programs for which a government activity plays a "contractor" role should implement this standard under a "contract" to the tasking government activity. A single, integrated set of technical tasks should be developed. This can be accomplished by integrating all the tasks in the contract's statement of work (SOW); tailoring this document to include tasks from other standards selected for contractual application; executing the complete, integrated task set via the Systems Engineering Management Plan (SEMP); or using some appropriate combination of these alternatives. Regardless of the approach taken to place the tasks of this standard on contract, the SEMP should be the single, integrated technical planning document.

This standard can be used by the government as follows:

a. For defining the government's requirements for systems engineering in a request for proposal (RFP) or contract. Toward this end, the requirements in this section can be applied by tailoring the requirements in Subsection 3.2 and definitions in Appendix C consistent with the objectives and constraints of the program and contract, or by developing tailoring for additional government, NSS industry, or professional society systems engineering standards to bring them into compliance with Sections 3.2 and Appendix C. The resulting document(s) should then be included in the list of compliance documents in the RFP.

b. To be incorporated by reference in Section M of the RFP, "Evaluation Criteria and/or Source Selection Standards" for evaluating either of the following:

   (1) Proposed alternative standards or corporate policies.

   (2) Further tailoring of a standard listed in the RFP.

   The tailored standard that proves to be acceptable to the government should then be placed on contract as a compliance document.

c. As a "checklist" for monitoring the contractor's systems engineering processes and products.

This standard applies to all acquisition phases of DODI 5000.02. The requirements herein provide important steps in implementing DOD direction to managed acquisition programs through the application of a systems engineering approach that optimizes total system performance and minimizes total ownership costs. The continuous application of a robust systems engineering methodology also serves as a way to ensure effective sustainment of weapon systems through design and development of reliable and maintainable systems.

Many other DOD directives and instructions, such as those for affordability, safety, and human factors, also require "the continuous application of a robust systems engineering methodology."

While all of the requirements in Subsection 4.2 collectively respond to these directives, those under Tradeoff Analyses and Effectiveness and Cost Analyses are specifically responsive.

Similarly, systems engineering is a core issue to be addressed at each major milestone review.

5.2 Systems Engineering—Concept

Systems engineering (SE) is the interdisciplinary approach for encompassing the entire set of scientific, technical, and managerial efforts needed to provide a set of life cycle balanced system solutions that satisfy customer needs. Throughout this standard, "balanced" refers to system requirements and/or the corresponding design for which the capabilities to be provided, cost, schedule, risk, and potential for evolutionary growth have been assessed and found to be acceptable in the context of the program that is to satisfy the requirements. The SE process is an iterative, disciplined method that includes requirements analysis, requirements allocation, design synthesis, and technical management processes. This process takes place over the entire life cycle, from needs definition to system disposal, and applies to all levels of acquisition from systems of systems (SoS) to individual platforms, systems, subsystems, and components. System success is dependent on the extent to which these systems satisfy their stakeholders' needs, are affordable, are acquired on time, work with other systems in a coherent family of systems, and can be changed over time to meet changing requirements. Stakeholders consist of:

(1) All individuals and organizations whose mission success is enabled by the capabilities embodied in the systems.

(2) All individuals and organizations responsible for system operations and maintenance.

Both the tasking organization and the performing organizations perform the systems engineering process and activities. Together they must manage requirements, including managing change, so that stakeholders' needs are always reflected in the most recent requirements baseline. The focus of this document is on the requirements for the contractor, but information is provided to assist the government. Systems engineering is thus a disciplined acquisition approach that requires identifying stakeholder requirements to a level of detail sufficient to design and build the system, to make trades between alternative means of satisfying these requirements, to select the tradeoff alternatives that balance performance, cost, schedule, risk, and potential for evolutionary growth, and to identify the interfaces (both internal to the system and external to it) necessary so that the system or family of systems can achieve success. It is vitally important that systems engineering be approached as the discipline guiding all acquisition activities and not as a compliance afterthought.

Systems engineering defines a tradespace—the set of possible solutions to stakeholder needs. The government should ensure that:

(1) A wide-enough tradespace is defined so that a reasonable range of tradeoff decisions can be made.

(2) The specific design, which includes the hardware and software needed to achieve a solution, is left to the contractor.

There are two systems engineering perspectives. Both are needed to help ensure successful systems acquisitions.

The first is that of a series of discrete steps occurring sequentially over time. Here, work products are successively refined through various control gates, such as technical reviews or acquisition phases. The second perspective is that a set of technical activities occurs throughout the entire life cycle. This set includes requirements analysis, verification and validation, test, and synthesis. Further, these activities must address the system functions needed for the system's development, operation, maintenance, and, eventually, disposal. The technical activities set thus pertains to the process of designing and implementing a system. The system functions, which must be addressed by the technical activities, pertain to the product itself.

While this technical activities set is performed over the life cycle, the relative importance of each of the activities will vary, as will the produced work products. Early on in the life cycle, for example, requirements analysis will be emphasized more heavily than test, and the work products produced will consist of high-level operational architectures. On the other hand, later in the life cycle, during detailed design, the importance of test relative to other activities will increase. The output work products produced will likely be detailed specifications at the subsystem level.

Through successive iterations of the systems engineering process, the system will be decomposed into subsystems. Some of these, in turn, will be further decomposed into lower-level subsystems. For each system or subsystem so defined, the technical activities set will be performed to:

(1) Translate the input requirements and architectures into a build-to specification (the allocated baseline).

(2) Define the inputs to yet another, lower-level set of subsystems.

Systems engineering thus provides an effective means to deal with the modern system's complexity. A complex problem is transformed into a succession of smaller problems. These are, in turn, transformed into still smaller problems. This process continues until a hardware/software solution can be implemented.

Throughout this iterative process, the outputs of technical activities must be integrated and reviewed at the control gates occurring at discrete points in time. These reviews are part of the contract management activities that ensure that time and budget are being well spent, and that progress is sufficient to ensure that the required capabilities will be delivered in a timely and cost-effective manner. Thus, a disciplined acquisition approach is achieved. The work products are matured over control gates as appropriate to the specific acquisition phases. The systems engineering technical activities (requirements analysis, functional analysis/allocation, synthesis, and systems analysis and control) span all control gates. And these technical activities must address all functions needed across the system's life cycle.

Tailoring the systems engineering process is achieved by deciding (1) which control gates to use and (2) how far to decompose the system and, thus, how much iteration of technical activities is needed for successful system acquisition. For example, a relatively simple system (e.g., a single black box to be installed on a weapon system) will likely require fewer decomposition levels and technical activity iterations than would the whole weapon system. Likewise, a purely software system would likely have different control gates than would a hardware and software system.

Systems engineering supports the DOD acquisition process, implementing:

(1) A shift from a requirements basis to a capabilities basis for designing a system.

(2) Insistence that systems function together as well as separately.

(3) Explicit recognition that systems must be changed over time to meet changing needs.

5.3 Data Requirements

In the development of national security space systems, it is the responsibility of the government to ensure that adequate systems engineering processes are implemented. Systems engineering data requirements for contractor(s) need to be established during preparation of the request for proposal and the contract. Contract Data Requirements List (CDRL) items enable the government to specify to the contractor(s) what SE data is required and when needed. These Data Item Descriptions (DIDs) must be listed, as applicable, on the Contract Data Requirements List (DD Form 1423) when this standard is applied on a contract in order to obtain the data, except where DOD FAR Supplement 227.405-70, Data Requirements exempts the requirement for a DD Form 1423.

SE CDRL Item Reference:

1.	Systems Engineering Management Plan (SEMP)	DI-SESS-81785
2.	Risk Management Plan	ISO 17666:2003
3.	Configuration Management Plan	DI-CMAN-80858B
4.	System Verification Deliverables	AIAA-S-117-2010, Annex B and D
5.	System/Segment Interface Control Specification	DI-SESS-81314A
6.	Logistics Management Information	DI-ALSS-81529 DI-ALSS-81530
7.	System/Subsystem Specification	DI-IPSC-81431A
8.	Contract Work Breakdown Structure (CWBS)	DI-MGMT-81334C
9.	Integrated Master Schedule (IMS)	DI-MGMT-81650
10.	Design Review Information Package	DI-SESS-81757A
11.	Engineering Change Proposal (ECP)	DI-CMAN-80639C
12.	Failure Summary and Analysis	DI-RELI-80255
13.	Data Accession List (DAL)	DI-MGMT-81453A
14.	Human Systems Integration Plan	Appendix D of this document

Many of the Data Item Descriptions (DIDs) to be used in CDRL preparation are maintained in an online database, the Acquisition Management Systems and Data Requirements Control List (AMSDL) within the Acquisition Streamlining and Standardization Information System (ASSIST), maintained by the Defense Logistics Agency. The AMSDL contains source documents and data item descriptions that have been approved for repetitive contractual application in DOD acquisitions.

5.3.1 Tailoring Guidance

This standard should be tailored to the specific requirements of a particular program, program phase, or contractual structure as directed by the government. Tasks that add unnecessary costs, data, and any factors that do not add value to the process or product should be eliminated. Tailoring takes the form of deletion (removal of tasks not applicable), alteration (modifying tasks to more explicitly reflect the application to a particular effort), or addition (adding tasks to satisfy program requirements). Tailored requirements and task statements may be used in preparing solicitation documents as well as by offerors in response to a request for proposal.

5.3.2 Tailoring Considerations

The systems engineering process and products discussed in this standard are applicable to all aspects of system development, irrespective of complexity, risk, or scope. However, the system functions to which these processes will be applied (as well as the number and sequencing of technical reviews, the use of iteration and recursion, and the specific systems engineering model and artifacts produced) will vary, depending on the specific system being developed and contractual requirements. In addition, the relative intensity of the various systems engineering activities within the systems engineering process can also vary from one system acquisition to the next. Tailoring of this guidance informs the government of the contractor's choice of tools, measurements, metrics, and specific systems engineering methods and tasks. The contractor's tailoring of this guidance is subject to the government's direction and approval.

The objectives of the contract define the breadth and depth of the systems engineering process for that specific procurement. To assist in tailoring the application of SE requirements in this document and the associated level of effort for systems engineering tasks in a particular procurement, the following inputs should be considered.

5.3.2.1 Applicable Acquisition Guidance

Systems may be acquired under different acquisition guidance, such as DOD or NRO regulations, depending upon who the acquiring organization is. These may have a different emphasis regarding upfront versus follow-on effort, and the degree of system definition required at the various acquisition milestones and reviews.

5.3.2.2 Acquisition Strategies

Evolutionary acquisition is described in the DOD 5000 series and is the preferred strategy for rapid acquisition of mature technology. Evolutionary acquisition delivers capability in increments or spirals, which have quite different implications for systems engineering.

Competitive prototyping is described in the Weapons Systems Acquisition Reform Act (WSARA) of 2009 as a preferred strategy for Phase A (and earlier) acquisitions.

5.3.2.3 New Development vs. COTS Systems [3]

COTS-intensive systems will generally require greater attention to selection of the COTS components, engineering the integration and assembly sequence, to integration and assembly of the COTS components, and to technology refresh.

5.3.2.4 Software vs. Hardware and Software Systems

Systems that are predominantly software in nature will typically use different control gates than will systems that consist of both hardware and software.

5.3.2.5 System Size and Complexity

In general, systems that are very large and complex will require more control gates and milestones, and more elaborate entry and exit criteria.

5.3.2.6 System Scope

Prototype systems, systems not intended for production and operational deployment, and systems not requiring any disposal (for example, software systems) will employ different control gates and processes.

5.3.2.7 Magnitude of Technical Risk

Systems that have significant technical risk will generally require more systems analysis and control early in the life cycle than will low-risk systems.

5.3.2.8 Policies, Regulations, Standards, and Laws

Policies, regulations, standards, and laws will influence the system functions to which the systems engineering process will be applied.

5.4 Robustness and Flexibility

Many systems produced by the DOD and intelligence communications (IC) are very expensive and take many years to develop and field. It is desired that these systems remain useful, even if the mission for which they were originally intended changes or if they must be adapted for a different mission. The terms "robustness" and "flexibility" are often defined relative to requirements and mission. A system is robust if it remains useful even as the external environment, which governs its mission as well as the threats it must face, changes. However, the functional requirements may be sufficiently broad so that these environment changes do not materially impact them. A flexible system, on the other hand, will remain useful even if its functional requirements as well as the external environment change in some significant way. Flexible and robust systems are contrasted with optimized systems, which cannot readily be adapted to major changes in the environment or in functional requirements [4]. These concepts are represented in Figure 5-1. The B-58, in the lower left quadrant, was optimized for a single mission, that of delivering nuclear weapons at supersonic speeds and at high altitude. Because it was only marginally useful for any other role, it became obsolete when Soviet air defenses improved with the addition of long-range, high-altitude surface-to-air missiles. The B-52, on the other hand, shown in the upper right-hand quadrant of Figure 5-1, has proven adaptable to both a changing external environment and to changes in its functional requirements. Starting life as a high-altitude nuclear bomber, it has been adapted to the low-altitude nuclear, tactical (conventional), and cruise missile carrier roles. Systems for which the functional requirements change even as the environment remains stable are poorly designed; i.e., the requirements did not accurately capture the capabilities needed in the first place.

It should be noted that inexpensive, short-lived, optimized systems might be completely appropriate for some mission applications. In situations of great volatility where required operational capabilities and technical requirements are likely to undergo extreme change, an inexpensive, "throwaway" system may be preferable to developing and fielding a much more sophisticated system that also takes longer to develop and that is much more costly.

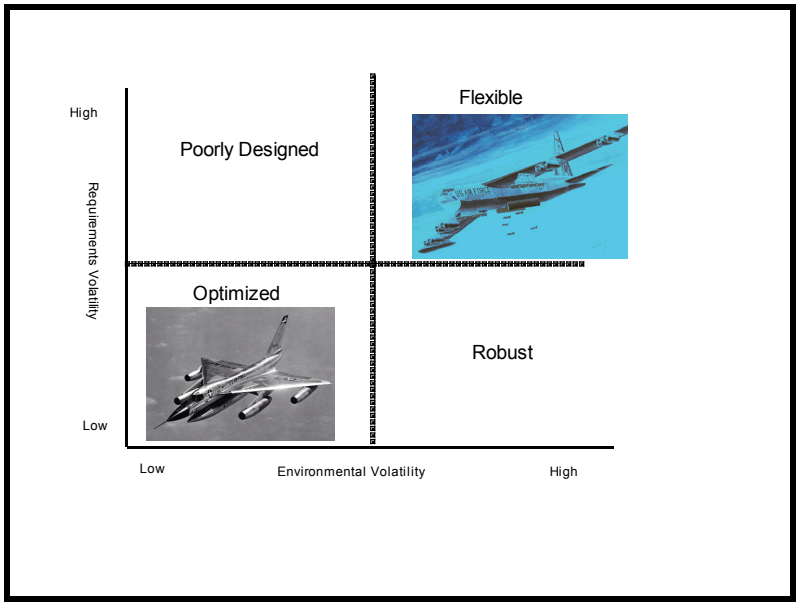

Figure 5-1. Flexible, robust, and optimized systems.

5.5 Evolutionary Acquisition

Evolutionary acquisition (EA) is described in the Defense Acquisition Guidebook (DAG) as the preferred DOD strategy for rapid acquisition of mature technology for the user. An evolutionary approach delivers capability in increments, recognizing, up front, the need for future capability improvements. The objective is to balance needs and available capability with resources, and to put capability into the hands of the user quickly. The success of the strategy depends on consistent and continuous definition of requirements as well as the maturation of technologies that lead to disciplined development and production of systems that provide increasing capability toward a materiel concept [5].

EA proceeds in increments and spirals. In a spiral, the system end state and the detailed functional requirements driving that end state are unknown at the time the spiral is started. Functional requirements are defined through interaction with stakeholders as well as through experimentation and wargaming. In an increment, by contrast, the end-state functional requirements are known. However, for various reasons, the government may defer achieving some functional requirements until later increments. The reason often cited for such deferments is that the technology required to achieve the functional requirements is too immature, and that risk reduction programs must be implemented before this technology can be safely or cost effectively integrated with the system. EA programs typically consist of both increments and spirals.

A systems engineering program that effectively supports EA has several characteristics:

- Detailed requirements and specifications are developed for the current spiral or increment. Implementation that is to occur after this spiral has many fewer detailed requirements. In the case of a spiral effort, only the most general requirements may be known for future spirals.

- Plan for growth with available bandwidth, electrical power, HVAC, etc., to ensure that future functional requirements can be accommodated.

- The Test and Evaluation Master Plan (TEMP) is tailored for the current spiral.

- The Life Cycle Management Plan (LCMP) accounts for multiple versions of the same system since systems fielded in different spirals or increments will be somewhat different. Alternatively, a decision may be made to modify all systems so that they comply with some standard.

6. References

[1] SMC Systems Engineering Primer and Handbook, 3rd ed., 29 April 2005, Appendix C9.

[2] SMC Systems Engineering Primer and Handbook, 3rd ed., 29 April 2005.

[3] Horowitz, Dr. Barry, "Learn as You Go Systems Engineering: A Methodology for System Assembly," as presented to the International Council on Systems Engineering (INCOSE).

[4] Workshop on Systems Engineering for Robustness, 8–9 June 2004, Lean Aerospace Institute, Massachusetts Institute of Technology, and Assistant Secretary of the U.S. Air Force for Acquisition.

[5] Defense Acquisition Guidebook (DAG), http://akss.dau.mil/.

Appendix A: Foundation for the Systems Engineering Process

The government (SPO) should develop or assemble and maintain the following types of data over the program life cycle to serve as the foundation for the systems engineering process. Unless otherwise prohibited by security or policy, the government should formally transmit the data to the system contractor(s) and tailor the requirements to define the use the contractor is to make of each.

Two lists follow. The first list applies to developing and maintaining the foundation for all contractual activities for both pre-acquisition contract phases, including support to the definition of capability gaps that must be filled by materiel programs, analysis of materiel approaches, analysis of alternatives, system concept selection, or development of a statement of capability needs by the operators and users as well as for all subsequent acquisition contract phases. The second list applies to the additional foundation that usually applies to acquisition contract phases.

a. The systems engineering foundation to be developed and maintained for all contract phases:

   (1) Any and all results produced by the capability needs process, to include:

      (a) Any functional (or mission) area analyses, plans, concepts, road maps, or other related planning documents.

      (b) Joint Capabilities Integration and Development System (JCIDS) documents including but not limited to Capability Production Documents (CPD) and Capability Description Documents (CDD) or updates of Operational Requirement Documents (ORD).

      (c) Any applicable Operational Views (OVs) or System Views (SVs) as defined in the DOD Architecture Framework.

      (d) The Concept of Operations or Operational Employment Concepts.

   (2) System Technical Requirements Document (TRD)—the document that identifies the acceptable system solution trade space. It may include functional and performance requirements that are identified as "to be determined," "to be reviewed," "to be resolved," or "to be supplied" as well as a verification strategy. The data in the document is used by the performing activity to initiate Requirements Analysis. As the program evolves, the system technical requirements are refined/resolved, incorporated into the requirements baseline, and captured in the system specification.

   (3) Applicable Acquisition Decision Memorandum (Memoranda)—documents system requirements, objectives, goals, or tradeoffs, specifically including guidance on life cycle cost or affordability, technology readiness levels, schedule, or sustainment objectives.

   (4) System threat assessment or current descriptions for relevant threats by the DIA or a service intelligence agency. (Note: The potential threats can depend on the technical characteristics of the solution(s), so the threat assessment should be reviewed and updated as the solution(s) evolve).

(5) Interface/interoperability requirements or constraints imposed by other systems with which the solution must operate or share a boundary (such as the interface between launch and satellite system, physical and functional characteristics of electrical, RF, and software links to other systems, including that for telemetry and control, interfaces with systems or components supplied by associate contractors, interfaces with facilities, or interfaces with other systems in a family or system of systems—the latter may be covered to a degree in the SVs listed above.)

(6) Applicability of standards in the DOD Information Technology Standards Registry required for compliance to the net-ready key performance parameter.

(7) Characteristics of the operating space and terrestrial environments. These usually depend on the characteristics of the solution(s) such as the orbit chosen for the space elements.

(8) Constraints on life cycle resource requirements to include total budget, budget phasing, and personnel manpower or skill levels.

(9) Schedule needs or constraints, including those imposed by the military need, planned deliveries under other contracts, or anticipated technology maturation.

(10) For both context and completeness, the latest Joint Vision, DOD Strategic Plan or DOD Quadrennial Defense Review (QDR), applicable Joint Operations Concepts, and analysis of doctrine, organization, training, materiel, leadership, personnel, and facilities (DOTMLPF) and other related joint, DOD, and service (component) planning documents and any relevant portions in the SE foundation and the information transmitted to the contractor(s).

b. The systems engineering foundation to be developed and maintained to the extent practical for any contract phase that includes drafting, approving, or maintaining baselines, specifications, or their equivalent below the system level and such steps as preliminary design, detailed design, or design verification:

(1) Capability Development Document (CDD), Capability Production Document (CPD), or Operational Requirements Document (ORD) updates.

(2) Analysis of Alternatives (AoA).

(3) Constraints imposed by law and regulation to include acquisition, environmental, safety and hazards control, human factors, radio frequency utilization, etc., including current versions of DOD, NSS, and the Air Force (or other agency) policy directives and associated instructions in each of these areas.

(4) System Technical Requirements Document. As the program evolves, this becomes the Draft System Specification and then the approved System Specification, including all approved changes thereto.

(5) Other specifications and standards in the SMC technical baseline[3] as well as handbooks and manuals related to systems engineering to include program management; work breakdown structures; configuration management; interchangeability, flexibility and expansion, and standardization; specification practices; technical reviews; risk analysis and management; software requirements analysis and development; security (physical security protection, entry/access control), personnel reliability (screening/security program), communications security (COMSEC), computer security, emanations security (TEMPEST), operations security, and information security (INFOSEC); Computer Resources (Memory and/or Processing Capacity Reserve, Portability of Software); test to include testability and design and test margins for environmental and operating conditions; climatic conditions; launch site and launch range; logistics or sustainment; nameplates and product markings; training; modeling and simulation; maintainability and diagnostics; product assurance; parts, materials, and related processes; safety; reliability, survivability; mass properties; human factors and human engineering; quality; workmanship, producibility, transition to production, and manufacturing; drawing practices (especially for hardware planned for second source procurement); EMI/EMC, including electrical referencing and ground, electrical bonding, and electrical shielding; corrosion prevention and control; electrostatic discharge control; welding, soldering, and printed circuit/wiring boards; and subsystems (including moving mechanical; pressure vessels; electrical power development, including solar arrays, storage, and distribution; electro-explosive and ordnance; metals including dissimilar metals; composites; and structures, including load fators and factors of safety).

(6) For ballistic missiles and other systems that involve nuclear weapons or radiation sources such as power sources, the additional program requirements, including independent reviews for nuclear safety and surety, or radiation safety, should be identified.

(7) The level to which vulnerabilities to each threat are to be controlled, or the basis (such as tradeoff ground rules) by which such levels are to be determined/recommended by the contractor(s).

(8) Support or sustainment concept/approach, or the basis by which the contractor is to develop the concept—identify key stakeholders, including the operator/users/maintainers.

(9) Training concept/approach, or the basis by which the contractor(s) is/are to develop the concept—identify key stakeholders, including the operator/users/maintainers, Air Education and Training Command (or other service/agency training, education, doctrine organizations), and any others responsible for training.

(10) The definition of certification criteria for Operational Safety, Suitability, and Effectiveness (OSS&E) and Space Flight Worthiness Certification and required contractor support to and/or certifications of readiness at independent, mission, flight, and/or launch readiness reviews. (See SMC Supplement to AFI 63-1201 and SMC Guides 120 through 1204.)

[3] Contact SMC/EA for the current SMC technical baseline.

(11) Philosophy, approach, and requirements for Test-Like-You-fly (TLYF) and Initial or Follow-on Operational Testing (IOT&E and FOT&E)—identify key stakeholders, including the Operator/Users and the organization responsible for operational testing and evaluation (OT&E).

(12) List of government-furnished equipment (GFE), property (GFP), materiel (GFM), and facilities.

Appendix B: Acronyms

This section provides a list of acronyms and abbreviations used in this standard, with associated meaning. This section is not a mandatory part of this standard. The information contained herein is intended for guidance only. (Note: many terms used below are defined in Section 3.2.)

AFMC	Air Force Materiel Command
ANSI	American National Standards Institute
APB	acquisition program baseline
ASR	alternative systems review
C/SCS	cost/schedule control system
C/SSR	cost/schedule summary report
C4I	command, control, communications, computers, and intelligence
C4ISR	command, control, communications, computers, intelligence, surveillance, and reconnaissance
CAIV	cost as an independent variable
CARD	cost analysis requirements description
CCPD	combat capability production document (also written C-CPD)
CDD	capability development document
CDR	critical design review
CDRL	contract data requirements list
CFE	contractor-furnished equipment
CFR	critical fault risk
CI	configuration item
CJCS	Chairman of the Joint Chiefs of Staff
CLIN	contract line item number
CONOPS	concept of operations
COTS	commercial off the shelf
CPD	capability production document
CPI	critical program information
CRD	capstone requirements document
CSCI	computer software configuration item
CSOW	contract statement of work
CSU	computer software unit
CWBS	contract work breakdown structure
DIA	Defense Intelligence Agency
DID	data item description
DOD	Department of Defense
DODAF	DOD architecture framework
DOTMLPF	doctrine, organization, training, materiel, leadership and education, personnel and facilities
EA	evolutionary acquisition
ECP	engineering change proposal
EDMs	engineering development models
EIA	Electronic Industries Alliance
ESOH	Environmental Safety and Occupational Health
EVMS	earned value management system
FCA	functional configuration audit
FMECA	failure mode effects and criticality analysis

FoS	family of systems
FOT&E	follow-on operational test and evaluation
FQR	formal qualification review
FRACAS	Failure Reporting Analysis, and Corrective Action System
FRD	functional requirements document
FRP	full rate production
GFE	government-furnished equipment
GFI	government-furnished information
GFM	government-furnished materiel
GFP	government-furnished property
HSI	human systems integration
HWCI	hardware configuration item
HWU	hardware unit
ICA	independent cost assessment
ICD	initial capability document; interface control document (or drawing)
ICE	independent cost estimate
ILSP	integrated logistics support plan
IMP	integrated master plan
IMS	integrated master schedule
IAW	in accordance with
IOC	initial operational capability
IOT&E	initial operational test and evaluation
IPA	integrated program assessment
IPAT	integrated program assessment team
IPD	integrated product development
IPPD	integrated product and process development
IPT	integrated product team
IRS	interface requirements specification
I&T	integration and test
JCIDS	Joint Capabilities Integration and Development System
JTA	joint technical architecture
KDP	key decision point
KPP	key performance parameter
LCC	life cycle cost
LMU	logistics management information
LOE	level of effort
LYF	Like You Fly
MCFA	mission critical fault analysis
MIL-HDBK	Military Handbook
MIL-SPEC	Military Specification
MIL-STD	Military Standard
MMD	mean mission duration
MNS	mission need statement
MOE	measure of effectiveness
MOP	measure of performance
NDI	nondevelopmental item
NEPA	National Environmental Policy Act
NSS	National Security System; national security space
O&S	operations and support

OA	operational architecture
ORD	operational requirements document
OSA	open system architecture
OSS&E	operational safety, suitability, and effectiveness
OT&E	operational test and evaluation
OV	operational view
PCA	physical configuration audit
PDR	preliminary design review
PESHE	programmatic environmental, safety, and occupational health evaluation
PHS&T	packaging, handling, storage, and transportation
PWBS	program or project work breakdown structure
RFP	request for proposal
SE	systems engineering
SEMP	systems engineering management plan
SEP	systems engineering plan
SFR	system functional review
SFW	space flight worthiness
SMC	Space and Missile Systems Center
SoS	system of systems
SOW	statement of work
SPO	system program office
SQIC	Space Quality Improvement Council
SRR	system requirements review
STAR	system threat assessment report
STE	special test equipment
SV	systems view
SVR	system verification review
T&E	test and evaluation
TA	technical architecture (as in TA View)
TBD	to be determined
TBR	to be resolved
TBS	to be supplied
TEMP	test and evaluation master plan
TLYF	Test Like You Fly
TOR	technical operating report
TPM	technical performance measure
TRD	technical requirements document
TRL	Technology Readiness Level
TRR	test readiness review
TV	technical view, technical standards view, or technical architecture view
UPC	unit production cost
WBS	work breakdown structure

Appendix C: Definitions

Acceptance – Verification that a component or configuration item meets requirements and workmanship standards and is suitable for use in its intended function.

Allocated baseline – Includes (1) the physical hierarchy, (2) the initially documented, validated, and approved design-to functional and performance requirements and design constraints for each system product in the hierarchy and all changes thereto approved in accordance with the contract, and (3) separable documentation identifying all design-to requirements and constraints for each component or computer software item and each separately integrated grouping of components and/or computer software items.

Allocation – (1) All or a subset of requirements for a higher-level system element that has been designated to be satisfied by a lower-tier element; (2) the act of decomposing the requirements for a system among the elements of the system.

Alternative systems review (ASR) – A formal technical review, usually conducted early in the acquisition life cycle of a system or evolutionary increment or spiral, of (1) support to the capability needs process, (2) an assessment of selected system concept(s) relative to system effectiveness in the intended environment, potential for growth, affordability, timeliness, and risk, and (3) the risks for the preferred system concept(s) that should be addressed during subsequent phases.

Analysis of alternatives (AoA) – The evaluation of the operational effectiveness, operational suitability, and estimated costs and risks of alternative system concepts to meet a mission capability. The analysis assesses the advantages and disadvantages of alternatives being considered to satisfy capabilities, including the sensitivity of each alternative to possible changes in key assumptions or variables.

Attribute – (1) A quality, property, or characteristic of a systems engineering product; (2) a testable or measurable characteristic that describes a characteristic of a system or capability.

Balance – The act of assessing and comparing capabilities to be provided, cost, schedule, risk, and evolvability for alternative requirements, requirements allocations, functional architectures, and/or designs to include identifying the capabilities or constraints that drive or otherwise cause high sensitivity to cost, schedule, or risk.

Baseline – Document(s) or decision database(s) that record the current set of requirements for the system and its design or system product solutions.

Capability – The ability to execute a specified course of action. It is defined by an operational user and expressed in broad operational terms in the format of an initial capabilities document or a recommendation to change doctrine, organization, training, materiel, leadership, education, personnel, and facilities.

Change control – The engineering management function of (1) limiting change to a baseline or other product to that which has been (a) assessed for impacts to capabilities, cost, schedule, risk, and growth potential and (b) approved by documented procedures in accordance with the contract, and (2) assuring implementation of all changes so assessed and approved to the products of the program.

Commercial off the shelf (COTS) – A system product that is available in the commercial marketplace that does not require unique government modifications or maintenance over its life cycle to meet the requirements.

Component – A system product that is an aggregation of hardware and/or software items that is viewed as a separate entity for purposes of design or some other reason, and for which the design is separately verified. Hardware items may be further divided into additional components, other lower-tier products (sometimes given names such as subassemblies), parts, materials, processes, and data; software items may be further divided into software units.

Concept of Operations (CONOPS) – A high-level concept whose purpose is to describe a problem that combatant commanders may face, objectives to solve the problem, desired effects, capabilities needed to achieve effects, and sequenced actions that describe the employment concept.

Configuration item (CI) – The aggregation of system elements that satisfies an end use function and is designated for separate configuration management.

Contract Work Breakdown Structure (CWBS) – Work breakdown structure (WBS) prepared by the developer to capture all work planned under the contract or subcontract and that is accepted by the customer.

Cost analysis requirements description (CARD) – The description of the salient programmatic and technical features of the program and the system it is to provide that is used by the teams preparing cost or schedule analyses or cost estimates.

Cost as an independent variable (CAIV) – An approach to the acquisition of military systems in which cost can be treated as a military requirement and cost, schedule, and performance may be traded within the tradespace between the objective and the threshold.

Critical design review (CDR) – During system development, the review by the contractor and the government of (1) the status of any changes to the functional baseline and architecture and allocated baseline since they were established, (2) the design baseline for each configuration item, including the completeness and compatibility of interfaces between the items as well as between the items and other systems, facilities, and personnel, (3) the basis for each element in the design baseline in terms requirements and objective, comprehensive, quantitative design trades, (4) the balance between performance, cost, schedule, and risk for each element in the selected design baseline, (5) the two-way traceability from the source of the functional baseline to the design baseline and back, and (6) the verification that the design baseline can meet the contract requirements.

Critical fault risk (CFR) – A risk associated with an unexonerated potential fault or flaw that would lead to mission failure.

Demonstration – The verification method of determining performance by exercising or operating a system product in which instrumentation or special test equipment is not required beyond that which is inherent to the product and all data required for verification is obtained by observing operation of the product.

Deployment function – The process performed to take the products of a system or system upgrade from the completion of manufacturing and verification to a state of operational readiness.

Derived requirements – Requirements not explicitly stated in the capability need but that are inferred from the nature of the proposed solution; the applicable verification, manufacturing, rework, storage, transportation, operating, disposal, and support environments; policy; law; best engineering practice; or some combination of the above.

Design – An iterative decisionmaking process that produces plans by which resources are converted into products or systems that meet system requirements.

Design constraints – Requirements that form boundaries within which other requirements must be allocated or derived and system products must be designed. The constraints may be externally imposed—such as by an interface with another system—or result from decisions internal to the program or contract.

Design release baseline – The documented, validated, and approved (1) design for each system product, including integrated assemblies of products, and (2) the definition of government personnel manpower and skill levels necessary to operate and support the system and all subsequent changes thereto approved in accordance with the contract.

Design solution – The process that translates the output of the Requirements Development and Logical Analysis processes into alternative design solutions and selects the final design solution.

Design-to requirements – The allocated and derived verifiable technical requirements and design constraints to which the design of a system product—including hardware, software, processes, data, or new or modified government facilities—is to comply.

Developmental test and evaluation (DT&E) – Test and evaluation activities to (1) support technology selection, requirements analysis and allocation, and design and (2) verify compliance with the contract requirements.

Development function – The process performed to take a system or system upgrade from the statement of the capability needs to readiness for manufacturing, verification, training, deployment, operations, support, and disposal of the delivered system products. This standard does not require that the development function be addressed in defining the system functional requirements or performing functional analysis.

Disposal function – The process performed to ensure that the disposition of system products and by-products that are no longer needed or no longer useful complies with applicable security classification guidance, demilitarization policy, and environmental laws and regulations.

Earned value management system (EVMS) – A system used to measure the amount of work actually performed on a project (i.e., to measure its progress) and to forecast a project's cost and date of completion.

Environmental constraints or requirements – The expected worst-case impact of the environment on the system or system product as well as the system's or system products' allowed impact on the environment.

External interface – A design constraint comprising a boundary between a system and another system or facility.

Family of systems (FoS) – A set or arrangement of independent systems that can be arranged or interconnected in various ways to provide varying capabilities. The mix of systems can be tailored to provide desired capabilities, dependent on the situation.

Formal action – An act that follows a documented procedure and that is approved by the signature of an authorized individual recorded in a readily retrieved archive.

Function – A task to be performed to achieve a required outcome or satisfy an operational need.

Functional analysis and allocation – The determination of the top-level functions that are needed to accomplish the primary system functions over the life of the system, their relationship, and their decomposition to subfunctions to the point that each subfunction or set of subfunctions can be related to one and only one physical element in the allocated baseline, the allocation of the top-level requirements, and constraints in the requirements baseline to determine how well each function and subfunction must be performed, and the capture of the aggregate in a functional architecture.

Functional architecture – The result of functional analysis and allocation; the hierarchical arrangement of functions, their decomposition into subfunctions, the associated timelines, and the allocation of the performance requirements and constraints in the requirements baseline to the functions and subfunctions.

Functional configuration audit (FCA) – (1) For each configuration item, the formal examination of its functional characteristics to verify that it has achieved the requirements in its allocated baseline. (2) For a system, the formal examination of its functional characteristics to verify that it has achieved the requirements in the functional baseline.

Functional requirement – A task that must be accomplished to provide a needed operational capability (or satisfy an operational need or requirement).

Hardware – System products made of a material substance, excluding documentation (and not including computer software).

Hardware item – An aggregation of hardware that satisfies an end use function and is designated for purposes of specification, interfacing, qualification, configuration management, or other purposes.

Implementation – The process that yields the lowest-level system elements in the system hierarchy.

Increment – A useful and supportable operational capability that can be effectively developed, produced or acquired, deployed, and sustained. Each increment of capability will have its own set of threshold and objective values set by the operator/user.

Inspection – The verification method of determining performance by examining (1) engineering documentation produced during development or modification or (2) the system product itself, using visual means or simple measurements not requiring precision measurement equipment.

Integrated architecture (for interoperability) – A structure based on the definition of architecture as a structure of components, their relationships, and the principles and guidelines governing their design and evolution over time. Thus the integrated architecture shows components and their relationship and needed capabilities for such key military capabilities as interoperability and sustainment. An architecture description is defined to be an integrated architecture when products and their constituent architecture data elements are developed such that architecture data elements defined in one view are the same (i.e., same names, definitions, and values) as architecture data elements referenced in another view. The term "integrated architecture" refers to an architecture description that has integrated operational, systems, and technical standards views. That is, there are common points of reference linking the OV and the SV and also linking the SV and the TV.

Integrated Master Plan (IMP) – A contractual description of the events, significant accomplishments, significant accomplishment criteria, applicable documents, and critical processes necessary to satisfy all contract requirements. The completion of each significant accomplishment is determined by measurable significant accomplishment criteria. The significant accomplishments have a logical relationship to each other (such as parallel or sequential) and, in subsets, prepare for events. Each event is, in turn, complete when the significant accomplishments leading up to it are complete. Narratives that include objectives, governing documentation, and an approach describe the critical processes. The IMP includes an indexing scheme (sometimes called a single numbering system) that links each significant accomplishment to the associated CWBS element, event, significant accomplishment criteria, and tasks presented in the Integrated Master Schedule (IMS). Note: The data in the IMP defines the necessary accomplishments for each event, both for the contract as a whole and for each team or manager responsible for a specific CWBS element.

Integrated Master Schedule (IMS) – The schedule showing the time relationship between events, significant accomplishments, and the detailed tasks required to complete the contract including calendar dates, time spans, critical path, and slack. The IMS applies (and extends if necessary) the same indexing (or single numbering system) as used in the Integrated Master Plan (IMP). IMS tasks are directly traceable to plans and accomplishments of the Earned Value Management System (EVMS), though some EVMS plans or work packages such as those for level of effort (LOE) tasks need not be traceable to the IMS.

Integrate-to requirements – Instructions for integrating or assembling software units, hardware pats/assemblies/subassemblies, hardware or software items, or higher-tier components to build and subsequently verify still higher-tier components including the system. Part of the design release or product configuration baseline.

Integration – The process of incorporating the lower-level system elements into a higher-level element in the architecture.

Interface – The boundary between two or more systems, functions or other logical representations, or system products or between a system and a facility at which interface requirements or constraints are set. Interfaces can be physical or functional.

Interface control – The identification, documentation, and control of all interface requirements on a system or on the elements of a system.

Interface control document; interface control drawing (ICD) – Drawing or other documentation that depicts interface designs or elements of interface designs that satisfy interface requirements.

Interface requirements specification (IRS), interface specification – A repository for interface requirements that details the functional and physical relationships between systems or system products or between systems and facilities.

Interoperability – The ability of systems, units, or forces to provide data, information, materiel, and services to and accept the same from other systems, units, or forces and to use the data, information, materiel, and services so exchanged to enable them to operate effectively together. Interoperability includes both the technical exchange of information and the end-to-end operational effectiveness of that exchanged information as required for mission accomplishment.

Key performance parameter (KPP) – An attribute or characteristic considered most essential for an effective military capability.

Knowledge database (or decision database) – The linked and readily retrievable collection of data (including inputs and intermediate and final results) that provide the audit trail of decisions and their rationale from the initial statement of needed capabilities or operational requirements and design constraints to the current description of the system technical requirements and the system products (including facilities and processes) and government personnel that collectively satisfy the requirements.

Life cycle – The time scope of a system from the start of manufacturing, verification, and integration through deployment, training, operations, and support during all program phases, including upgrades, until final disposal of the system is complete.

Life cycle cost (LCC) – The total cost to the government, both sunk and anticipated, of acquisition and ownership of the system over its useful life. It includes the cost of research, development, test, and evaluation; procurement (to include production testing, deployment, and support to initial operation, test, and evaluation [IOT&E]); operations and support (to include training, IOT&E, and follow-on operational test and evaluation [FOT&E]); government facilities; and disposal. For defense systems, life cycle cost is also called total ownership cost (TOC).

Like You Fly (LYF) test – A prelaunch test based on operational timelines and other applicable mission characteristics.

Logical analysis – The process of obtaining sets of logical solutions to improve understanding of the defined requirements and the relationships among the requirements, including timeline events sequencing, behavioral, logical, and data flow (also see functional analysis and allocation).

Materiel approach or materiel solution – A defense acquisition program (nondevelopmental, modification of existing systems, or new program) that satisfies, or is a primary basis for satisfying, identified warfighter capabilities. In the case of family of systems or system of systems (FoS and SoS) approaches, an individual materiel solution may not fully satisfy a necessary capability gap on its own.

Mission – The task or tasks for which the system is designed. Typical missions from space are: communication, navigation, Earth science, reconnaissance, missile warning and tracking, nuclear event detection, Earth imaging for intelligence, signals intelligence, space science, and investigating the universe.

Mission Critical Fault Analysis (MCFA) – A top-down analysis that focuses on determining the events and sequences of events that can lead to mission failure in any phase of the mission up to and including nominal operations.

Mission phase – A portion of a mission that has a specific objective or set of objectives and has defined initiation and completion events. Mission phases will vary according to the nature of the mission area, but there is likely to be some commonality of phases between similar end items. Typical mission phases for a launch vehicle are prelaunch initialization, first stage, second stage, payload deployment, collision avoidance, and reentry. Typical mission phases for a space vehicle are prelaunch initialization, ascent, separation and initialization, orbit transfer, spacecraft and payload checkout, nominal operations, and disposal. Mission phases for a command and control system might include test, training, rehearsal, activation, shadow operations, initial operations, contingency (backup operations), maintenance, and sustainment. There are likely to be additional mission phases for more complex missions, involving constellations, multiple agencies, and multiple users.

Nondevelopmental item (NDI) – Any system product that is (1) available in the commercial marketplace or (2) previously developed and in use by a department or agency of the United States, a state or local government, or a foreign government with which the United States has a mutual defense cooperation agreement and that does not require unique upgrades or maintenance over its life cycle to meet the current requirements. System products that (1) have been developed but are not yet available in the commercial marketplace or in use by a government entity or (2) require only minor modification or upgrade are termed near-NDI (N-NDI).

Objective – An operationally significant increment above the threshold; the desired operational goal associated with a performance attribute, beyond which any gain in utility does not warrant additional expenditure.

Open standards – Widely accepted and supported standards set by recognized standards organizations or the market place. These standards support interoperability, portability, and scalability and are equally available to the general public at no cost or with a moderate license fee.

Operating conditions – The expected range of operating variables when a system or system product is performing as designed. Examples are temperatures, motion of mechanical assemblies, and pressures, such as in propulsion chambers, tanks, and plumbing.

Operational Test and Evaluation (OT&E) – Independent test used to determine the effectiveness and suitability of the system or system upgrade for operational use by typical military users and the evaluation of the results of such tests. Can be either initial (IOT&E) or follow-on (FOT&E). IOT&E is conducted on production or production representative articles to support a decision to proceed with production (usually to rate production if applicable). It is conducted to provide a valid estimate of expected system operational effectiveness and operational suitability. FOT&E is conducted during and after the production period to refine

the estimates made during IOT&E, to evaluate changes, and to reevaluate the system to ensure that it continues to provide the needed capability and retains its effectiveness in a new environment or against a new threat.

Operations function – The process performed subsequent to verification and deployment to accomplish a system's intended missions, excluding training, support, and disposal.

Operator – An operational command or agency that controls the acquired system for the benefit of users. Operators may also be users.

Performance requirement – A statement of the extent to which a function must be executed, generally measured in such terms as quantity, quality, coverage, timeliness, or readiness. See Functional requirement.

Physical configuration audit (PCA) – (1) For each configuration item (CI), the formal comparison of a production-representative article with its design baseline to establish or verify the product baseline. (2) For the system, the formal comparison of a production-representative system with its functional and design baseline as well as any processes that apply at the system level and the formal examination to confirm that the PCA was completed for each CI, that the decision database represents the system, that deficiencies discovered during testing (DT&E and IOT&E) have been resolved and changes approved, and that all approved changes have been implemented.

Physical hierarchy – The hierarchical arrangement of system components necessary to satisfy the requirements baseline and to which requirements are to be allocated. The top entry in the hierarchy is the system. Intermediate levels in the hierarchy include any groupings of components that are to be integrated for any purpose (such as verification, manufacturing, operations, or support) or that are needed for systematic requirements allocation. The hierarchy extends to include all hardware and software items necessary to satisfy the requirements baseline over the life cycle, whether deliverable or not. Also sometimes called the product tree or the physical architecture.

Preliminary design review (PDR) – During system development, the review by the contractor and the government of (1) any changes to the functional baseline since it was established, (2) the functional architecture, (3) the physical hierarchy, (4) the allocated baseline for each configuration item, including the completeness and compatibility of interfaces between the items and between the items and other systems, facilities, and personnel, (5) the basis and the balance between performance, cost, schedule, and risk for each element in the architectures and each requirement in the baseline, (6) the two-way traceability from the source of the functional baseline to the allocated baseline and back, and (7) the verification that the allocated baseline can meet the system requirements.

Primary system functions – The essential tasks that must be accomplished so that a system will provide the needed operational capability, implement DOD and military service policy, and satisfy public law over the life cycle.

Process – A procedure or treatment applied during the life cycle of a system. The steps to be taken and any required materials, procedures, tooling, or equipment are normally defined as part of the design and controlled as part of the design release or product configuration baseline.

Product baseline, product configuration baseline – The documented and approved update to the design release baseline for one or more system products after confirmation (1) of qualification that the product design satisfies all performance and functional requirements and constraints in the current allocated and design release baselines, (2) that the as-built, as-coded, or as-integrated product is accurately reflected in the baselines, and (3) for hardware products, readiness for continued production, acceptance verification, deployment, training, operations, support, and disposal and all subsequent changes thereto approved in accordance with the contract.

Product requirements analysis – The determination of complete and verifiable product functional and performance technical requirements and design constraints. These requirements and design constraints are based on functional analysis and allocation, allocation of constraints, and derivation of further requirements and constraints toward the achievement of a design that satisfies the requirements baseline and is balanced between capabilities to be provided and the evolutionary growth potential on the one hand, and cost, schedule, and risk on the other hand. The results of product requirements analyses are documented in the allocated baseline.

Qualification – (1) For hardware, the verification that a hardware item or higher level of integration, together with its embedded software, meets all requirements and constraints of the environmental and operating conditions anticipated over its life cycle, including specified margin to the maximum predicted flight environment (MPE); (2) for software, the verification that a software unit meets all requirements and constraints using operationally representative data in an operationally representative configuration.

Requirement – (1) A condition or capability needed by a user to solve a problem or achieve an objective; (2) a condition or capability that must be met or possessed by a system or system component to satisfy a contract, standard, specification, or other formally imposed documents; (3) a documented representation of a condition or capability as in (1) or (2).

Requirement reference – A higher-level requirement and/or an analysis, test, or other justification for a requirement, requirement allocation, or other baseline or functional architecture element.

Requirements acceptability criteria – Requirements that define a system that satisfies all user capabilities and requirements. All user requirements trace to system- and lower-level requirements.

Requirements analyses – The determination of complete and verifiable system functional and performance technical requirements and design constraints based on analyses of the needed operational capabilities, requirements, objectives (or goals), measures of effectiveness; missions; and projected utilization environments; DOD policies and practices; public law; and the balance between capabilities to be provided and the evolutionary growth potential on the one hand, and cost, schedule, and risk on the other hand. The results of requirements analyses are documented in the requirements baseline.

Requirements baseline – The documented, validated, and approved system-level (top-level) verifiable and allocable functional and performance technical requirements and design constraints, their allocation or assignment to the lower levels necessary to capture the systems engineering foundation for the program, and all changes thereto approved in accordance with the contract.

Requirements development – The process of taking all inputs from relevant stakeholders and translating those inputs into technical requirements.

Risk – The uncertainty of attaining a requirement, goal, or objective pertaining to technical performance, schedule, or cost and the consequences of not attaining it.

Significant accomplishment – A specified step or result that indicates a level of progress toward completing an event and, in turn, meeting the objectives and requirements of the contract.

Significant accomplishment criteria – Specific, measurable conditions that must be satisfactorily demonstrated before a significant accomplishment listed in an Integrated Master Plan (IMP) is complete and before work dependent on the accomplishment can proceed.

Software – Computer programs, procedures, and data pertaining to the operation of a computer system. Data may include, for example, information in databases, rule bases, or configuration data. Procedures may include, for example, interpreted scripts.

Software item – An aggregation of software that satisfies an end use function and is designated for the purposes of specification, interfacing, qualification testing, configuration management, or other purposes. A software item is composed of one or more software units. A software item is sometimes called a computer software configuration item (CSCI).

Software unit – An element in the design of a software item; for example, a major subdivision of a software item, a component of that subdivision, a class, object, module, function, routine, or database. A software unit is sometimes called a computer software unit (CSU).

Specification – A description of the verifiable technical requirements and design constraints for hardware and computer software, materials, and processes, along with the verification method for determining whether each requirement is met.

Support function – The process performed to facilitate uninterrupted operations and training. The tasks include the acquisition and supply of spares, depot-level maintenance, the acquisition and maintenance of the facilities, and selection and training of personnel.

Survivability – The capability of a system to avoid or withstand man-made hostile environments without suffering an abortive impairment of its ability to accomplish its designated mission.

System – An integrated set of products (to include processes and government facilities) and personnel that interact with one another in an organized or interrelated fashion toward a common purpose that cannot be achieved by any of the products alone or by all of the products without the underlying organization. The integrated products and personnel fulfill manufacturing, verification, integration, deployment, training, operations, support, and disposal functions to provide needed operational capabilities or satisfy objectives.

System concept – A rudimentary or unfinished design used for preliminary assessments of system effectiveness, cost, schedule, or risk that provides the basis for more detailed designs through further iteration of the requirements, functional, and design analyses as required by this standard.

System functional review (SFR) – A review, usually held prior to or early in the design or similar phase, by the developer and the customer to confirm that (1) technology maturity has been demonstrated and the risk reduction efforts planned prior to the start of design have been completed and the results have been reflected in the proposed requirements baseline and preliminary allocated baseline, (2) requirements analysis has progressed to the point that the proposed requirements baseline is accurate and comprehensive (though perhaps with TBDs, TBRs, and TBSs), (3) the preliminary allocated baseline reflects the proposed requirements baseline and is balanced with respect to performance, cost, schedule, risk, and potential for evolutionary growth, (4) the decision database supports two-way traceability from the source of the requirements baseline to the preliminary allocated baseline and from any element to the rationale for that element, (5) the assessment that the evolving allocated baseline can lead to a design that will satisfy the requirements baseline, (6) the preliminary physical hierarchy, the planned (or approved) PWBS, and the CWBS in place or proposed to be used subsequent to the SFR are all consistent, (7) the life cycle cost for the evolving design is consistent with the program affordability constraints, and (8) the remaining risks have been identified and can be handled in the context of the planned contract and program activities. The primary SFR data is the decision database documenting or demonstrating that these systems engineering requirements have been satisfied.

System effectiveness – Objective, quantifiable measure(s) (such as communications throughput, surveillance sensitivity, or navigation accuracy) that relate the system concept or design to the system technical functional and performance requirements and constraints.

System of systems (SoS) – A set or arrangement of interdependent systems that are related or connected to provide a given capability. The loss of any part of the system will degrade the performance or capabilities of the whole.

System product – A separately identifiable portion of a system other than personnel, whether delivered or not, to include hardware, software, firmware, process, government facility/equipment or modification of an existing government facility/equipment, modification to existing equipment or property, document, manual, drawing, instructions, data, or combination thereof. Services that are not system products but data that defines the required scope of services such as contractor support during IOT&E or operations are system products.

System requirements review (SRR) – A review, usually held near the end of the program definition and risk reduction or similar phase (Phase I), by the contractor and the government to confirm that (1) the planned risk reduction efforts are making adequate progress and reflect the technologies envisioned to implement the preferred system concept(s), (2) the operational requirements and objectives have been accurately and comprehensively translated into technical requirements and are reflected in the preliminary functional baseline, (3) the preliminary functional baseline and the plans to complete it account for the eight primary functions and all design constraints on the system design, (4) the preliminary physical hierarchy is consistent with the preliminary functional baseline, (5) life cycle cost projections remain consistent with the program affordability constraints, (6) the decision database supports two-way traceability from the source of the functional baseline to the functional baseline and from any element to the rationale for that element and shows the rationale and approval authority for all changes, and (8) the significant accomplishments and accomplishment criteria have been planned for the next wave of technical activity on the contract.

System technical requirements – Characteristics, attributes, or distinguishing features stated in terms of verifiable functional and performance requirements and design constraints that a system or system element must have within a defined environment or set of conditions, including the threat, in order to provide a needed operational capability and comply with applicable decisions by the milestone decision authority, policy, practices, and law. The system technical requirements are documented in the requirements baseline. Technical requirements for the elements of the system are allocated from the requirements baseline.

System threat assessment – Describes the threat to be countered and the projected threat environment. The threat usually depends on the technical characteristics of the design solution.

System Threat Assessment Report (STAR) – An intelligence document validated by the Defense Intelligence Agency (DIA) that serves as the single authoritative reference for threat data to be used in a weapon system acquisition program. The STAR contains the lethal and nonlethal threats against the system and the threat environment in which the system will operate.

System verification review (SVR) – A review, usually held near the end of development and prior to production, by the contractor and the government to confirm that (1) the system and its constituent products have been verified to satisfy the requirements, allocated, and design release baselines, including an assessment of the assumptions and methods used in verification by analysis, (2) deficiencies discovered during verification (DT&E) (and validation—IOT&E—to the extent completed) have been resolved and changes approved and implemented, (3) all other approved changes have been incorporated into the affected baselines and the affected system products verified to comply, (4) the life cycle cost projections remain consistent with the program affordability constraints, (5) the requisite plans, procedures, resources, and facilities are available (or on schedule) to initiate production, production verification, training, deployment, operations, support, and disposal, (6) the remaining risks have been identified and can be handled in the context of the planned program, and (7) the decision database has been maintained to capture all changes and updates so that it completely and accurately captures (a) the current approved baselines and (b) the verification data showing compliance with the baselines. The primary data for the SVR is the decision database documenting or demonstrating that these systems engineering requirements have been satisfied.

Systems engineering – As a process, service, function, or activity, an interdisciplinary effort to iteratively and recursively (1) support the evolution of, first, the integrated architectures, roadmaps, capability assessments, and Initial Capabilities Document (ICD), and then later, the Capabilities Development Document (CDD) and Capabilities Production Document (CPD) to guide the development program, (2) translate the needed capabilities and objectives into, first, a requirements baseline, second, an allocated baseline, third, a design release baseline, and, finally, a product configuration baseline, all of which collectively provide a design response to the capability needs that is balanced with respect to system effectiveness, cost, schedule, risk and evolutionary growth potential, (3) maintain those baselines over the life cycle of the system, (4) assess compliance with the baselines as development evolves, and (5) verify that the baselines have been met by products built, coded, bought, and integrated in accordance with the design, and then support the validation (through OT&E) that the needed capabilities have been provided.

Systems engineering plan (SEP) – Government document that specifies the scope of the technical effort required to develop and sustain the system or solution through its entire life cycle. At a minimum, the planning effort must define the government, contractor, and subcontractor tasks that will be accomplished; the allocation of responsibilities; what resources are needed; and how SE activities will be monitored, controlled, and integrated with the other aspects of the program. The SEP guides all technical aspects of the program. These plans are tied together in the program's Integrated Master Plan (IMP) and Integrated Master Schedule (IMS).

Systems engineering product – A tangible and documented result of systems engineering to include plans, tradeoff and other analyses, the baselines, the functional architecture, assessments, drawings, instructions, verification data, or validation results.

Systems engineering requirement – Statement describing a mandatory contract compliance element, attribute, or quality of the systems engineering activity.

System(s) view, system architecture view (SV) – A description, including graphics, of system(s) and interconnections providing for, or supporting, DOD functions. DOD functions include both warfighting and business functions. (1) For a domain, the SV shows how multiple systems link and interoperate in terms of the high-level internal construction and operations of particular systems within the architecture. (2) For the individual system, the SV emphasizes the physical connection, location, and identification of key hardware and software; it may also include data stores, circuits, and networks and may specify system and component performance parameters to show how the individual system supports the broader capabilities shown in the domain SV and any associated operational views (OVs). The SV associates resources to the operational view (OV) and its requirements per standards defined in the technical view (TV); see the definitions of these terms. See also integrated architecture. Several systems engineering products have been defined making up the SV; see Section 5 of the DOD Architecture Framework, Volume II, 15 January 2003.

Tailoring – The modification of text, figures, graphs, tables of specifications, standards, or other requirements or tasking documents to clarify the extent to which they are applicable to a specific acquisition contract.

TBD/TBR/TBS – TBD: "to be determined" by the developer (or formally recommended to the customer) based on analysis or test by a stated and documented date. TBR: the preliminary element is "to be resolved" by the developer (or recommended to the customer) based on analysis or test by a stated and documented date. TBS: "to be supplied" by the customer to the developer by an agreed-to and documented date.

Technical performance measure (TPM) – A measure comparing the current actual achievement for technical parameters with that anticipated at the current time and on future dates. Confirms progress and identifies deficiencies that might jeopardize meeting a system requirement. Assessed values falling outside the expected range indicate a need for evaluation and corrective action.

Test – The verification method of determining performance by exercising or operating the system or system product using instrumentation or special test equipment that is not an integral part of the system or system product being verified.

Test and evaluation master plan (TEMP) – A plan that correlates and integrates T&E with the overall acquisition program strategy, schedule, and other program documentation, and defines the critical path for completing test and evaluation. The TEMP will place the most emphasis on the next phase of system development rather than provide a historical account of program progress. The TEMP is usually updated prior to major milestones, program baseline changes, or when there have been significant changes to the program.

Test plan – Documented approach, resources, and schedule to verify compliance of a system or one of its elements by test or to obtain data to support a contract or program decision.

Test procedure – Documented list of equipment, manuals, and other required material and instructions to perform a test.

Test report – Documentation of compliance with the test plan and the compliance or noncompliance of the system products under test.

Threshold – A minimum acceptable operational value below which the utility of the system becomes questionable.

Total ownership cost (TOC) – Costs to research, develop, acquire, own, operate, and dispose of defense systems, other equipment, and real property; the costs to recruit, retain, separate, and otherwise support military and civilian personnel; and all other costs of the business operations of the DOD. At the individual program level, total ownership cost is synonymous with the life cycle cost of the system. See lifecycle cost.

Traceability – The ability to relate an element of the requirements baseline, functional architecture, allocated baseline, design release baseline, and product configuration baseline (or their representation in the decision database) to any other element to which it has a master-subordinate (or parent-child) relationship.

Tradeoff, tradeoff study – An objective comparison with respect to system effectiveness, cost, schedule, risk, and potential for evolutionary growth of all feasible alternative system requirements, functional architectures, allocated baselines, or designs. Can be used as the basis for selecting less capability in one area in order to achieve a more balanced overall system result.

Trade space – The set or range of feasible alternatives to be compared to achieve a solution that is balanced with respect to system effectiveness, cost, schedule, risk, and potential for evolutionary growth.

Training function – The process performed to achieve and maintain knowledge and skill levels necessary to perform the operations, support, and disposal functions efficiently and effectively over the system life cycle.

Transition – The process of moving the system element to the next level in the physical architecture or, for the end-item system, the user.

User – An operational command or agency that receives or will receive benefit (e.g., data or services) from the acquired system when it is in operation.

Validation – (1) For a baseline, the demonstration that it has its required attributes, that any assumptions necessary in its development are valid, and that the effectiveness of the emerging system design will satisfy the system technical requirements and constraint; (2) for a satellite or launch system, the certification that it is ready for launch; (3) for any other system, the assessment of the operational test authority that the system is suitable for operations and continued production, if planned.

Verifiable – Confirmable, capable of being tested (verified or falsified) by experiment or observation.

Verification – The process that confirms that the system and its elements meet the design-to or build-to specification.

Verification method – A finite, objective, reproducible way to prove that a solution meets a requirement. The verification methods are test, demonstration, inspection, and analysis.

Work Breakdown Structure (WBS) – A system product-oriented hierarchical tree composed of the hardware to be developed, produced, or sustained; software to be developed or sustained; services (including cross-product activities such as systems engineering); data; and facilities that encompass all work to be carried out under the program or contract along with a dictionary of the entries in the tree. The WBS for the entire program is called the program or project WBS (PWBS). The WBS for the work under a contract is called the contract WBS (CWBS) and is prepared in accordance with the contract.

APPENDIX D:
HUMAN SYSTEMS INTEGRATION PLAN

The following data item has been developed to provide improved clarity for efficient planning of an effective and affordable human systems integration effort. This data item comprises a tailoring of the currently approved Data Item Description, DI-HFAC-81743A. Use of this data item is highly recommended if not specified as a contractually deliverable or accessible item.

DI-HFAC-81743A/T (SMC)

DATA ITEM DESCRIPTION

Title: HUMAN SYSTEMS INTEGRATION PLAN

Number: DI-HFAC-81743A/T (SMC) Approval Date: TBA
AMSC Number: N/A Limitation: N/A
DTIC Applicable: N/A GIDEP Applicable: N/A
Office of Primary Responsibility: SMC/EN Applicable Forms: N/A

Use/Relationship: The Human Systems Integration Plan (HSIP) describes the contractor's Human Systems Integration (HSI) efforts; elements and activities supporting HSI domain requirements specified in the contract and any/all associated derived requirements; and how they will be managed and integrated with other program elements. The HSIP does not take the place of domain-specific plans such as the System Safety Plan; Training Plan; Programmatic Environment, Safety, and Occupational Health Evaluation; Human Engineering Program Plan (HEPP); or an HSI section in the Systems Engineering Management Plan, unless the procuring agency so directs.

a. This Data Item Description (DID) contains the format and instructions for preparing the HSIP content in response to applicable tasks delineated in the contract Statement of Work (SOW).

b. Where cited below, users refer, as applicable, to operators, maintainers, trainers, support personnel (including transporters), and manufacturers.

c. This SMC tailored DID supersedes DI-HFAC-81743A, dated 20110421.

d. For SMC contracts the HSIP shall be a separate plan and shall be summarized and referenced in the SEMP.

Requirements:

1. Compliance and Reference documents. The applicable issue of the documents cited herein, including their approval dates and dates of any applicable amendments, notices, and revisions, shall be as cited in the Acquisition Streamlining and Standardization Information System (ASSIST) database at the time of the solicitation, or as cited in the SOW of the request for proposal (RFP) or contract.

2. Format. The HSIP format shall be contractor selected and contain all the content elements described below as tailored per paragraph 3. The format used initially shall be used for subsequent

submissions. Revisions shall be clearly indicated in a manner consistent with standard editorial practices.

3. Tailoring. The HSIP shall be tailored to reflect the Statement of Work (SOW), system specification, and phase of development. The proposed tailoring of the HSIP content shall identify the paragraph, proposed changes, and rationale for the change(s). Tailoring specified by the procuring agency shall also be included. If no tailoring is proposed beyond that specified by the procuring agency, this shall be stated.

4. Content. The HSIP shall contain the information described in the following paragraphs.

(a) Front matter. Table of contents; lists of tables, figures, and appendices, as applicable; and a list of acronyms and abbreviations.

(b) Overview.

i. Provide the HSIP purpose and scope. Briefly describe the system, its concept of operations, mission, human role(s), operational environment, predecessor system(s), if any, and related HSI lessons learned. Provide the system acquisition category and current phase of development. Reference other program documents that may provide additional detail, as appropriate. If applicable, state when the next submission of the HSIP is due.

ii. Describe the overall HSI objectives for the program, the HSI domains that will be addressed, and the strategy for addressing HSI domain objectives individually and in domain trade studies. The HSI Domains shall comprise the nine (9) domains defined in AFI 63-1201, Attachment 5 (2011), AFI 63-101 (2010) Section 3.79, and/or the Air Force Human Systems Handbook. Each of the HSI domains shall be individually and specifically addressed. If any HSI domains will not be addressed, provide a rationale for the exclusion. Briefly describe the major activities that must be accomplished in applying HSI to the system development, consistent with the contract SOW, system requirements, specification(s), and work breakdown structure.

iii. Provide a list of HSI-related contract deliverables or accessible documents (e.g., Training Plan, Safety Plan, Manpower Estimate) for all domains deemed applicable in task 4.b.ii. For any section below whose content is substantially covered in another document, the contractor has the option of providing the required content in the HSIP or providing a summary of the content and referencing the document section(s) that contains the content.

(c) Organization.

i. Human Systems Integration organization. Identify, describe, and provide an organizational chart of the contractor's primary organization elements(s) and primary HSI organization elements, including the HSI Integrated Product Team, if any. Identify the HSI domain(s) addressed by each element; to whom the HSI manager/lead and HSI domain leads report; and the reporting and responsibility relationships between the HSI manager/lead and the HSI domain leads. For key positions (e.g., HSI manager/lead, domain leads, key practitioners), provide summary job descriptions and the minimum required qualifications.

ii. Human Systems Integration organizational relationships. Describe the relationships and responsibilities of the contractor's HSI organization element(s) to other contractor organization

elements responsible for areas affected by HSI, such as systems engineering; hardware and software design teams; training; test and evaluation; related disciplines (e.g., reliability, maintainability, supportability); applicable working groups; and government HSI counterparts.

iii. Human Systems Integration working group. Describe the composition of the HSI working group (e.g., contractor, subcontractor, and procuring agency HSI domain representatives and user group representatives), and its responsibility, authority, and accountability for ensuring compliance with HSI requirements. Provide a charter for the working group.

(d) Human Systems Integration Key Performance Parameters and Key System Attributes. Describe Key Performance Parameters (KPPs) and Key System Attributes (KSAs) with HSI implications considering all HSI domains deemed applicable in task 4.b.ii, above.

(e) Human Systems Integration support of affordability and performance goals. Describe the method(s) by which the contractor will identify and conduct tradeoffs between HSI domains and other program elements in support of primary HSI goals: to reduce total system ownership costs; improve total system performance; and ensure that the system accommodates the characteristics of the user population that will design, develop, manufacture, operate, maintain, train, and support it. Describe how the contractor will ensure that HSI cost and performance factors will be formally considered during analysis, design, and procedure development; during technical reviews (e.g., system requirements review, systems functional review, preliminary design review, or critical design review); and in the engineering change management process.

(f) Human Systems Integration issues and risks. Describe the method(s) by which the contractor will identify, document, validate, prioritize, coordinate, track, report, and resolve or mitigate HSI issues and risks over the life of the program. Describe the process for trading off HSI issues and risks among HSI domains, and between HSI and other disciplines. Describe the process by which HSI risks will be elevated to formal program-level risk management status.

(g) Human Systems Integration in subcontractor or interorganizational efforts. If subcontractors, including work transferred to other corporate divisions and the like, are responsible for work on hardware or software components that have operator, maintainer, or supporter interfaces, or other HSI efforts (e.g., serving as subject matter experts, performing trade studies), describe the subcontractor's organization element responsible for HSI and the subcontractor's HSI activities. Describe the process by which requirements for HSI will be levied, implemented, and integrated across subcontractors for all HSI domains. Describe the method(s) by which the prime contractor will monitor subcontract compliance with HSI requirements.

(h) Human Systems Integration in system analysis. Identify the HSI efforts in system analysis and the organizational element(s) responsible for their conduct. Describe how HSI domain area practitioners or subject matter experts will participate in:

1. Analyzing, flowing down, aligning, and deriving requirements.
2. Performing mission analysis.
3. Determining system functional requirements and capabilities.
4. Determining system architecture.
5. Allocating system functional requirements to humans, hardware, and/or software.

6. Developing system functional flows.

7. Performing system effectiveness analyses, studies, and modeling.

List the HSI analyses that will be performed to support system definition for all domains (e.g., manpower estimation, critical function analysis). For each analysis:

1. Provide a description or a reference to the paragraph(s) where it is described elsewhere in the HSIP or other document(s).

2. Identify any data, software, databases, models, or equipment required from the procuring agency.

(i) Human Systems Integration in system design. Describe the HSI effort (for all applicable domains) in system design to ensure fulfillment with the requirements and guidance documents for HSI specified in the contract. Describe HSI domain area practitioner or subject matter expert participation in:

1. The preparation of system design and performance specifications.

2. Selection of commercial off-the-shelf or nondevelopmental items.

3. Trade studies and analyses.

4. Mock-up evaluations and dynamic simulations.

5. Usability assessments.

6. Tests.

7. Detailed drawing reviews.

8. System and program technical reviews.

Describe the planned involvement of (and coordination to obtain) end-user personnel (e.g., operators, maintainers, trainers, and support personnel) in assessing the design, operation, maintenance, training, and support of the system. Describe and provide a rationale for the methodology and human performance criteria to be used.

(j) Human Systems Integration in procedure development. Describe the HSI domain area practitioner or subject matter expert role in creating, reviewing, and validating procedures for users. This involves activities such as developing operator manuals, interactive electronic technical manuals, and training media.

(k) [Reserved]

(l) [Reserved]

(m) [Reserved]

(n) [Reserved]

(o) [Reserved]

(p) Human Systems Integration in verification and validation. Describe HSI domain area practitioner or subject matter expert participation in the contractor's integrated test and evaluation program, including developmental (DT), operational (OT), and/or combined DT/OT planning or test execution. Describe how (e.g., methods, metrics, and tools) and when the contractor will verify the design for compliance with HSI requirements. Identify the number and role(s) of HSI personnel who will support test and evaluation. Provide a summary schedule that depicts HSI tests, evaluations, and other verification activities (inspections, analyses, and demonstrations) in support of program milestones.

(q) Data sources. Identify contractor, industry, technical society, and government standards, handbooks, and other documents that will be applied to HSI domain integration activities and any proposed tailoring.

(r) Human Systems Integration data products. Identify and briefly describe each HSI deliverable or accessible data product specified in the contract.

(s) Time-phase schedule and level of effort. Provide a milestone chart that identifies each separate HSI activity to be accomplished during the contract period of performance. Include key HSI decision points and their relationship to program milestones. Provide information on the proposed number of personnel on an annual basis.

(t) HSI quality control. Describe the approach for assessing and reporting on the quality (relative success and progress) of the overall HSI effort and each HSI domain over the course of the contract. Describe the:

1. Approach for assessing the following contributors to HSI success.
2. Implementation of HSI policy and processes.
3. Implementation of a human-centered design process;
4. Education and qualifications of HSI personnel.
5. HSI involvement in subcontractor requirements and selection.
6. Availability and use of HSI tools.
7. HSI participation in testing and verification.

End of DI-HFAC-81743A/T (SMC).

SMC Standard Improvement Proposal

INSTRUCTIONS

1. Complete blocks 1 through 7. All blocks must be completed.
2. Send to the Preparing Activity specified in block 8.

NOTE: Do not use this form to request copies of documents, or to request waivers, or clarification of requirements on current contracts. Comments submitted on this form do not constitute or imply authorization to waive any portion of the referenced document(s) or to amend contractual requirements. Comments submitted on this form do not constitute a commitment by the Preparing Activity to implement the suggestion; the Preparing Authority will coordinate a review of the comment and provide disposition to the comment submitter specified in Block 6.

SMC STANDARD CHANGE RECOMMENDATION:	**1. Document Number**	**2. Document Date**
3. Document Title		

4. Nature of Change
(Identify paragraph number; include proposed revision language and supporting data. Attach extra sheets as needed.)

5. Reason for Recommendation

6. Submitter Information

a. Name	**b. Organization**
c. Address	**d. Telephone**
e. E-mail address	**7. Date Submitted**

8. Preparing Activity

Space and Missile Systems Center
AIR FORCE SPACE COMMAND
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El Segundo, CA 91245
Attention: SMC/EN