AEROSPACE REPORT NO.
TOR-2005(8583)-3

Systems Engineering

15 April 2005

Edited by

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Systems Planning and Engineering

Prepared for

SPACE AND MISSILE SYSTEMS CENTER
AIR FORCE SPACE COMMAND
2430 E. El Segundo Boulevard
Los Angeles Air Force Base, CA 90245

Contract No. FA8802-04-C-0001

Systems Planning and Engineering Group

THE AEROSPACE CORPORATION
EL SEGUNDO, CALIFORNIA

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Note

This TOR contains a new draft version of Military Standard 499, Systems Engineering. It incorporates suggested revisions to the MIL-STD-499 and the "B" revision to that document, which was never officially released. It was prepared by and SMC team that included Aerospace, government, SETAs, and independent consultants. This draft has had only limited review by SMC SPOs and industry. This draft is being published at this time to support near-term SMC acquisitions with the intent of using it as a compliance standard.

The goal is to reissue this draft standard as an SMC standard. Prior to that, further review by SMC organizations, discussions with industry, and coordination with other agencies such as the NRO and NASA are planned.

Acknowledgments

The MIL-STD-499C is the result of contributions received from many individuals from a wide spectrum of technical disciplines. The names and organizations of the principal contributors, or those acting as the focal point of contact for their organizations, are listed below.

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MILITARY STANDARD

SYSTEMS ENGINEERING

AMSC AREA MISC

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MIL-STD-499B 2.70

Foreword

This standard is approved for use by all Departments and Agencies of the Department of Defense (DoD) and may be used by other government and commercial organizations. Send comments and pertinent data for improving this standard to HQ SMC/AXEM, 2420 Vela Way, Los Angeles, CA 90245 or email to Dave Davis at david.davis@losangeles.af.mil.

This standard captures the key aspects of DoD policy to be included in the next revision of the DoD 5000 series as well as the National Security Space Acquisition Policy (NSSAP) 03-01 guidance to apply a robust systems engineering approach that balances total system performance and total ownership costs within the family-of-systems, systems-of-systems context. This standard defines the government requirements for an executable contractor systems engineering process and required systems engineering efforts to assist in defining, performing, managing, and evaluating systems engineering efforts in defense system acquisitions and technology developments. The scope of systems engineering is defined in terms of what should be done, not how to do it. The requirements in this standard, including those for systems engineering management, are defined in terms of the required systems engineering products and the required attributes of the products.

This standard provides a reference to the Government for analyzing competing contractor proposals and for evaluating the contractor's systems engineering program once on contract. The government will perform initial tailoring of this standard to address appropriate program scope, appropriate program size, and progress within the acquisition life cycle. The standard and tailoring, if any, will be part of the draft and final Requests for Proposal (RFP) along with instructions for contractors to perform further tailoring as part of their proposal submittals.

This standard provides the technical foundation for integrating product and process development. This requires the simultaneous development of system products and life-cycle processes to satisfy user needs; multidisciplinary teamwork; and a Systems Engineering Process (SEP). The Integrated Master Plan (IMP), the Systems Engineering Management Plan (SEMP), and/or other plans or policies, to the extent required by the RFP and contract, describe the implementation of these by each Contractor organization with technical responsibilities. The IMP/SEMP/SEP and/or other systems engineering plans and policies required by the RFP and contract are intended to coordinate, integrate, and execute all technical aspects of the program in accordance with the requirements of this standard.

This standard governs the conduct of a complete, integrated technical effort (systems engineering), not the organizational entity or method of implementation. The organization of resources employed to implement this standard is expected to vary from one program implementation to another.

This standard integrates the entire technical effort. This includes requirements from other standardization documents selected for contractual implementation, but does not replace them. Each program implementation will employ other standards to satisfy program requirements and to comply with DoD

policy. It is the Program Manager's responsibility to select and tailor those standards, which are necessary to execute the program successfully.

This standard must be conscientiously tailored to ensure that only necessary and appropriate requirements are cited in defense solicitations and contracts. Tailoring guidance can be found in MIL-HDBK-248, Acquisition Streamlining, and in paragraph 6.3 of this document.

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1. Scope

1.1 Document Purpose

This standard's purpose is to describe and require a disciplined systems engineering approach in system acquisitions. This document is primarily intended to be used by Government agencies (Department of Defense, the Intelligence Community, NASA, and others); it is equally applicable to civil and commercial developments. It is thus a compliance document to be applied to performing activities in system acquisitions. Performing activities are generally private contractors or subcontractors engaged by the Government to design and produce, but sometimes also to operate, maintain, and dispose of weapon systems, information systems, software systems, command and control and C4I systems, intelligence systems, and other materiel systems. This standard is primarily intended to define requirements for performing activities; tasking activities will also use it as a guide to assist in systems engineering planning and management. Tasking activities will generally be agencies responsible for acquiring, operating, and maintaining systems and families of systems.

This standard's objectives are defining the minimum essential work products, produced in the systems engineering process, needed to:

(1) Adequately define a system over its life cycle such that the integrated system, when deployed, provides at least the threshold or minimum needed capabilities and is affordable, but otherwise balances capability, cost, schedule, risk, and the potential for evolutionary growth. The system is defined by operations concepts, operational capabilities/
requirements, system architectures, specifications, drawings, technical orders, training documents, maintenance facilities and equipment documents, test plans and procedures, and other documents 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. The system definition products satisfying this objective are referred to as the system configuration baseline.

(2) Define clear-cut intermediate development stages to be used by the tasking and performing activities to plan, monitor, and control the progress over each phase and contract of the system acquisition program such that the first objective is achieved effectively and efficiently. The intermediate development stages are defined in terms of the increasing accuracy and completeness of three preliminary results called the requirements, allocated, and design release baselines. The development stages are then defined in terms of the maturity of each of these baselines at key technical reviews and audits.

1.2 Responsibility for Success

The Government is responsible for the system acquisition's success. This responsibility cannot be assigned or delegated to the Contractor or to any other organization. The Contractor is responsible for executing to terms and conditions, performance requirements, and service-level agreements as specified in the contract or memorandum of understanding by which the Contractor's services were acquired.

1.3 Systems Engineering—Concept

Systems Engineering (SE) is an interdisciplinary approach 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.[1] 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, and (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 trade space, the set of possible solutions to stakeholder needs. The Government should ensure that (1) a wide enough trade space is defined so that real tradeoff decisions can be made; and (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,

1 *Air Force Instruction 63-XXX (Draft),* 05 January, 2005, Disciplined Systems Engineering Process

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 that occur 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), or (2) define the inputs to yet another, lower-level set of subsystems. Systems engineering thus provides an effective means to deal with the modern systems' complexity. An intractably 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 and software solution can be implemented.

Throughout this iterative process, the technical activities' outputs, the work products for the systems and subsystems, must be integrated and reviewed at the control gates occurring at discrete points in time. These reviews 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 those provided by 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) what control gates and (2) how far to decompose the system and, thus, how many iterations of technical activities are 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, as codified in DODD 5000.1, the DODI 5000.2, the CJCSI 3170, the NSSA 03-01, Directive 7 and related documents. These documents:

shift from a requirements to a capabilities basis for designing system; (2) insist that systems function together, as well as separately; and (3) explicitly recognize that systems must be changed over time to meet changing needs.

2. Reference Documents

The following documents are referenced in this standard (The reference numbers do not imply order of precedence):

(1) National Security Space Acquisition Policy 03-01, 27 December, 2004

(2) Department of Defense Directive 5000.1, May 12, 2003, http://akss.dau.mil/darc/darc.html.

(3) Operation of the Defense Acquisition System, DoDI 5000.2, May 12, 2003

(4) Joint Capabilities Integration and Development System, CJCSI 3170.01C, 24 June 2003

(5) Operation of the Joint Capabilities Integration and Development System, CJCSM 3170.01, June 24, 2003

(6) DoD Architecture Framework, Version 1, Volumes 1 and 2, 15 January 2003

(7) Joint Technical Architecture, Version 6, 3 October, 2003

(8) Cost Analysis Guidance and Procedures, DoD 5000.4-M, December 1992

(9) Work Breakdown Structure, MIL-HDBK-881, January 2, 1998

(10) SMC Systems Engineering Primer & Handbook, 15 Jan. 2004, 2nd Edition

(11) INCOSE Systems Engineering Handbook, v2.0 July 2000, International Council on Systems Engineering Sec. 2.3

(12) Defense Acquisition Guidebook, December 20, 2004

(13) DoD 5010.12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL)

(14) MIL-STD-1521C Draft—Technical Reviews and Audits for Systems, Equipment, and Computer Software

(15) Defense Acquisition Desk Book (DAD), Sec 3.3.1, http://akss.dau.mil/dag/DoD5000.asp?view=document&rf=DoD5002\Procedures_3.3.asp

(16) Space Flight Worthiness, SMCI 63-1202, 1 Oct. 2002

(17) Military Standard-Test Requirements for Launch, Upper Stage, and Space Vehicles (Draft) Aerospace report No. TOR-2003(8583)-1, 19 December, 2002

(18) MIL –STD-973, Configuration Management, 17 April 1992

(19) DoD Information Technology Standards Registry, DoDD 4630.5, 5 May 2004

(20) Global Information Grid, DoDI 4630.8

(21) Risk management, ISO 17666, 1 April 2001

(22) Reliability Program, MIL-STD 1543B

2.1 Order of Precedence

Order of precedence of documents in this standard is as follows: (1) This Standard, (2) Other referenced documents.

Figures in this standard are for example only. If there is a conflict between the text and the figures, the text applies.

3. Acronyms and Definitions

A glossary of essential definitions for systems engineering is contained in Appendix A, and a list of acronyms is included in Appendix B.

Appendix A provides definitions of essential terms used in the standard. This Appendix is a mandatory part of the standard. The information contained herein is intended for compliance.

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4. General Requirements

This section defines the systems engineering tasks and required system engineering products across the system life cycle for any program, new development, upgrade, modification, resolution of deficiencies, or development and exploitation of technology. These systems engineering tasks are to be performed throughout the system life cycle; however, the outputs produced by these tasks will be highly dependent on the position in the life cycle. For example, early in the life cycle, the products produced will consist primarily of high-level operational architectures. Later, the products will consist of detailed subsystem specifications. The Systems Engineering Process in Figure 4.1 is an iterative process starting with requirements analysis, proceeding to functional analysis and requirements allocation, then to synthesis. Iteration can occur within a given step or via the verification and validation feedback loops. The outer feedback loop represents the verification that the evolving design can satisfy the functional and performance requirements and meet the design constraints identified in Requirements or final design System analysis, and control is to be performed throughout the systems engineering process.

Each of Subsections 4.2.1 through 4.2.8 defines one or more general requirements corresponding to a step in the flow diagram in Figure 4.2. Following each general requirement, detailed requirements

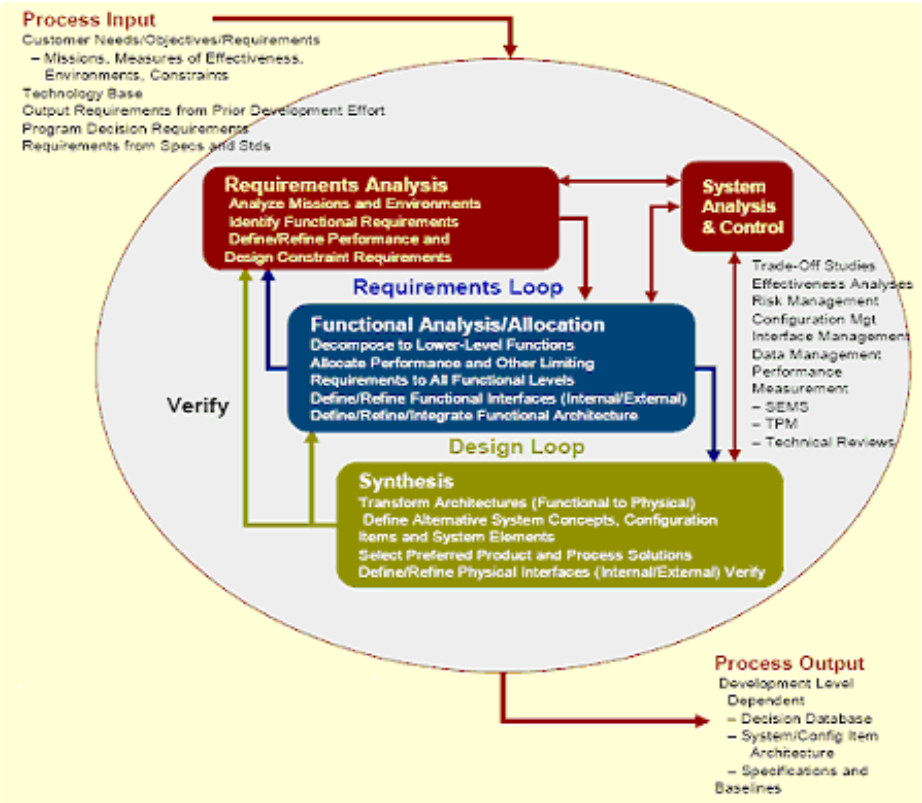

Figure 4.1. The System Engineering Process (SEP)

are then stated, usually in terms of required systems engineering products and the required attributes for each systems engineering product. Each instance of the phrase **"**Required Systems Engineering Products**"** is followed by a list of products required to comply with the general requirement. Thephrase "Required Product Attributes" indicates required characteristics of the required systems engineering products. The compliance requirements are denoted by use of the verb shall.

4.1 System Engineering Process Application

The Contractor shall apply the systems engineering process of requirements analysis, functional analysis/allocation (to include architectural definition and requirements derivation), synthesis, and systems analysis and control (Figure 4.1)[2] progressively throughout the effort to define requirements, designs, and solutions for the system life cycle, and to achieve contractual objectives.

4.2 Systems Engineering Requirements

Figure 4.2 is a view of the System Engineering Process shown in Figure 4.1 that relates the activities of Figure 4.1 to the evolving Requirements, Allocated, Design Release, and Product Configuration Baselines. The numbers in parenthesis represent the paragraph numbers in the text. Also, the individual blocks that make up Figure 4.2 are grouped in larger blocks to show the relationship with Figure 4.1. The data that form the System Engineering Program foundation, which the Government should maintain throughout the program, serve as essential inputs to start the process. See Appendix C for a detailed list of data that may form a part of the foundation. If data necessary to perform systems engineering are not provided or not complete, the Contractor shall prepare timely drafts of the required information and transmit them to the Government for approval along with the reasons that the data are needed and the date when resolution is needed.

4.2.1 Requirements Analysis and Validation

Using the data forming the System Engineering Program Foundation that have been provided or approved by the Government, requirements analysis and validation shall be performed iteratively toward ultimately satisfying requirements 4.2.1 through 4.2.4 and IAW 4.2.5 and 4.2.8. and 5.3.1 through 5.3.7 below and all subsections thereto to develop the system technical requirements and constraints.

4.2.1.1 Required System Engineering Products

a. Validated, approved, and maintained requirements baseline captured in a Technical Requirements Document (TRD), draft System Specification, and then final System Specification, and system-level Interface Control Documents (ICDs) or interface specifications or their electronic equivalents defining all system-level requirements and constraints and their allocations to the next lower level.

b. Requirements Traceability Matrix.

2 SMC Systems Engineering Primer & Handbook, 15 Jan 2004.

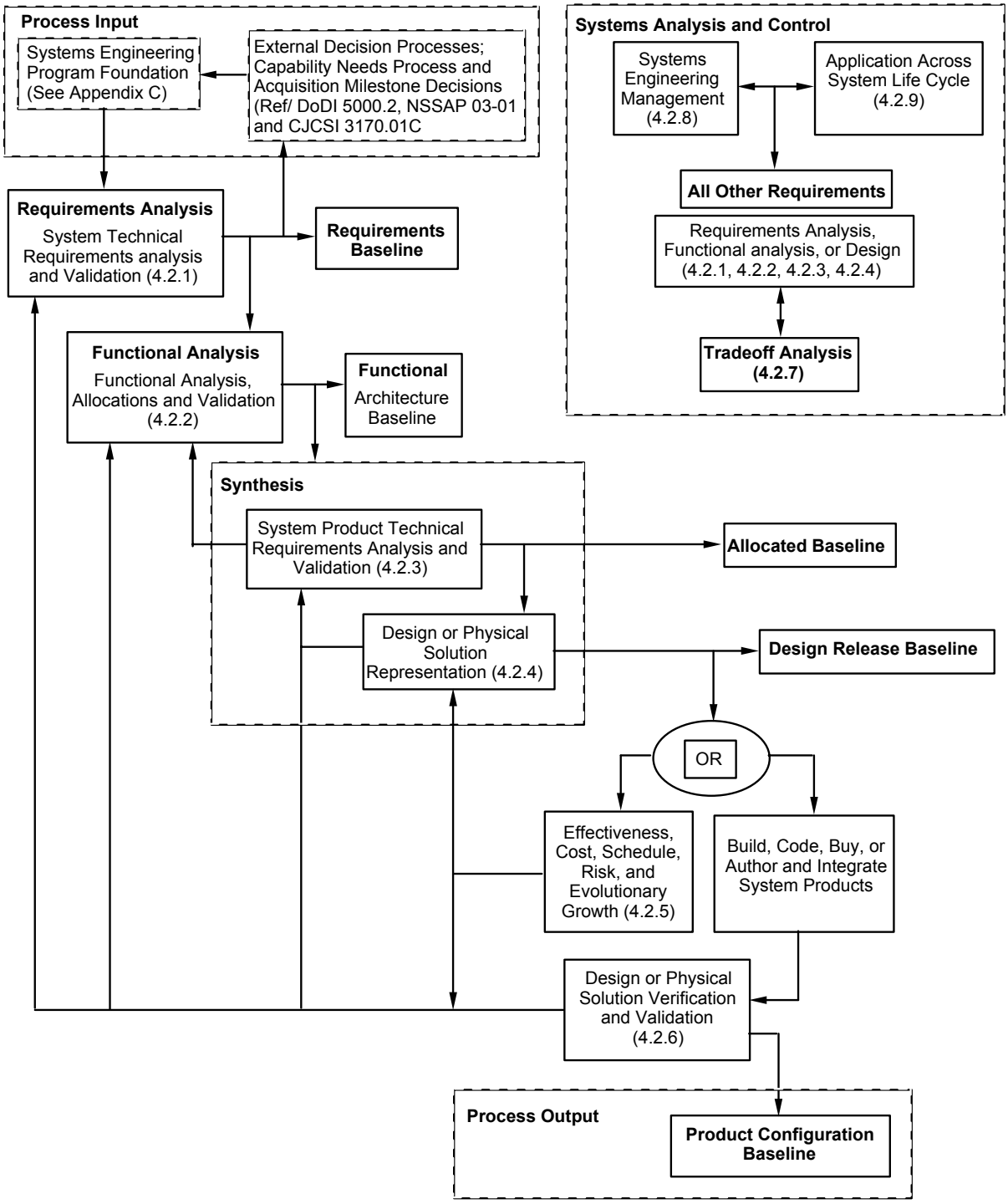

Figure 4.2. Relationship between minimum essential systems engineering requirements and baselines.

c. Source and engineering basis including each trade-off or other analysis for each system-level system performance and functional requirement and its allocation to the next lower level.

4.2.1.2 Required Attributes

a. The requirements baseline shall:

(1) Trace to the capabilities for which the system is being designed and to the missions for which it is intended. This traceability between mission, capability, and requirements shall be maintained and kept up to date at all times.

(a) The information in the System Engineering Foundation (Appendix A) shall be arranged hierarchically where missions and Concept of Operations information are the top, and shall trace to capabilities below that, then trace down to the system technical requirements and constraints that then trace to baselines. In addition, the hierarchy will link the other data in the System Engineering Foundation to this hierarchy as appropriate to show links and perform analysis.

(b) Each higher-level requirement shall be sufficiently defined to adequately form the basis for complete, accurate, and verifiable requirements at lower levels.

(c) Each lower-level requirement shall be analyzed to ensure that it is valid, necessary, and sufficient to satisfy the higher-level capabilities, requirements, or constraints from which they resulted.

(d) Trace attributes, needed to adequately perform Systems Engineering, shall be constructed and maintained.

(2) Encompass the minimum Operator/User capabilities to be and otherwise balance the capabilities with the cost, schedule, risk, and potential for evolutionary growth.

(3) Include system interoperability, including those defined in operational or system views created to show interoperability needs or interface constraints IAW the DoD Architecture Framework.

(4) Include all functional and performance requirements and constraints and those imposed by each specialty function (see Subsection 5.2).

(5) Include 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.

(6) Be documented in a system specification or TRD and captured in the decision database.

b. The Requirements Traceability matrix shall:

(1) Trace among the system technical requirements, capabilities, and missions. It shall trace capabilities upward to mission and downward to functional and performance requirements at the system level.

(2) This matrix shall be maintained such that changes to any requirement, capability, system, software module, or physical component ripple through the traceability matrix.

(3) Identify and track changes.

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

(5) Be captured in the requirements database.

c. The basis for each element of the requirements database shall include a reference to the documented capability need, other source, constraint, and/or the tradeoff or other analyses, and shall be captured in the decision database and linked to the element.

(1) Include a verification requirement and verification method of analysis, inspection, demonstration, or test to balance cost and schedule impacts with the risk to the program and the operational mission.

(2) Be two-way traceable from system technical requirements to functional architecture/logical representation to design/physical solution representation to verification methods, plans, procedures, and data.

(3) The analyses shall ensure consistency with the Operator/User expectations or Concept of Operations as well as other information identified in Appendix C appropriate to the program phase as approved or modified by decisions by the Milestone or other program Decision Authorities.

(4) The analyses shall define the requirements and constraints consistent with a range of operational scenarios that encompass the anticipated usage.

(5) The analyses shall identify the capabilities, requirements, and constraints that drive cost, schedule, or risk.

(6) The analyses shall ensure that the system requirements are feasible, have acceptable risk, result in high confidence in affordability with current budget and allocation of budget across performance years, and result in high confidence of delivering acceptable products in the scheduled time.

(7) Be captured in the decision database.

(8) Each higher-level requirement shall be sufficiently defined to adequately form the basis for complete, accurate, and verifiable requirements at lower levels.

(9) Each lower-level requirement shall be analyzed to ensure that they are both necessary and sufficient to satisfy the higher-level capabilities, requirements, or constraints from which they were allocated.

(10) The requirements shall be validated to ensure that the system will perform as expected in its intended operational/user environment through Government involvement and review.

4.2.2 Functional Analysis, Allocations, and Validation, or Logical Solution Representation[3] Definition and Assignment and Validation

Functional/logical analyses, allocations/assignments, and validation shall be performed iteratively with 4.2.1 and 4.2.3 through 4.2.5, and 5.3.1 through 5.3.8 based on tradeoffs in accordance with 4.2.7 and 4.2.8 to develop a functional architecture or logical representation of the system, which shall be captured in the decision database.

4.2.2.1 Required System Engineering Products

A functional architecture or set of architecture views.[4]

4.2.2.2 Required Attributes

a. The resulting functional architecture or logical solution representation shall:

3 Logical solution representation is used here in the sense of ANSI/EIA-632-1998 and elaborated on in the note on page 23 of that document: "NOTE—Functional analysis, object-oriented analysis, structured analysis, and information engineering analysis are recognized approaches found in text books and other literature to develop logical solution representations in terms of, for example, functional flows, behavioral responses, state and mode transitions, timelines, control flows, data flows, information models, object services and attributes, context diagrams, threads, data structures, and functional failure modes and effects."

4 DoD Architecture Framework, Version 1, Volumes 1 and 2, 15 January 2003

(1) Accurately and completely reflect the functional and performance requirements in the requirements baseline.

(2) Accurately and completely reflect the minimum or threshold required operational capabilities consistent with decisions by the program decision authorities, concepts of operation, system behavior, and required functionality in order to identify all requirements and constraints before the commencement of detailed design or purchase/acquisition of material, parts, or components.

(3) Accurately model the system behavior to include all sequencing, concurrency, and timing requirements.

b. The functional architecture or logical solution representations at each level shall be 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.

c. Each top-level function or logical element shall be decomposed to lower levels to the point that:

(1) Each can be related one-to-one to elements of the physical hierarchy (see 4.2.3 below) to form the allocated baseline;

(2) The allocation of the top-level performance requirements and design constraints to the lower levels is complete; and

(3) The aggregate is captured in a functional architecture.

d. The decision for each decomposition, grouping, sequencing, timing, iteration, and concurrency that is chosen shall be supported by documented tradeoff or other analysis.

e. Justification or supporting rationale shall be documented in the decision database for the relationships to the physical solution that are selected.

f. Data flow relationships shall be established to determine data associations that are necessary to derive requirements from the functional or logical analyses.

g. Interfaces shall be defined at the earliest possible time and to as great a detail as is possible. The Contractor shall address how the interface will be physically implemented, as well as the logical issues such as data formats, data semantics, etc. Where possible, the Contractor shall use industry standard interface technologies and protocols. Moreover, point-to-point interfaces and proprietary or unique technologies will, to the extent possible, be avoided; common interfaces that serve many system components and that leverage industry standard protocols and technologies will be used wherever possible.

4.2.3 System Product Technical Requirements Analysis and Validation

The Contractor shall conduct requirements analysis and validation.

4.2.3.1 Required System Engineering Products

a. The validated, approved, and maintained allocated (design-to) baseline in specifications and interface documents or their electronic equivalent grouped by each system element such as segment, subsystem, component (H/W and S/W), computer software unit, and part that is to be designed or provided by a separate design team or contractor such that the requirements baseline will be satisfied.

b. The basis for the definition or selection of the products in the physical hierarchy.

c. Separable documentation for each component or computer software unit.

4.2.3.2 Required Attributes

a. The allocated baseline shall:

(1) Be developed iteratively IAW 4.2.1, 4.2.2, 4.2 4, and 4.2.5, based on tradeoffs IAW 4.2.7 and planning, monitoring and decisions, and control IAW 4.2.8.1through 4.2.8.3.

(2) Include the physical hierarchy that identifies all system products, and shall establish the interactions of the system.

(3) Include the design-to technical functional and performance requirements and design constraints for each product in the physical hierarchy allocated IAW 4.2.2 or from higher-tier elements in the physical hierarchy such that requirements baselines will be fully satisfied over the system life cycle.

(4) Include all derived design-to requirements and design constraints for each product in the physical hierarchy.

(5) Include all interfaces that shall be defined at the earliest possible time and to as great a detail as is possible. In addition, in defining interfaces, the Contractor shall address how the interface will be physically implemented, as well as the logical issues such as data formats, data semantics, etc.

(6) Include a verification method of analysis, inspection, demonstration, or test selected for each requirement and constraint.

(7) Be captured in the decision database.

b. The bases for the elements of the allocated baseline shall:

(1) Be captured in the decision database and linked to each element.

(2) Include the tradeoff or other analyses for the selection for the structure and system products in the physical hierarchy.

(3) Include the source requirement and/or tradeoff or other analyses for each allocated or derived requirement and constraint in the allocated baseline.

c. Separable documentation for system products in the allocated baseline shall identify all design-to requirements and constraints and each corresponding verification method.

4.2.4 Design or Physical Solution Representation

The Contractor shall design the products that constitute the system.

4.2.4.1 Required System Engineering Products

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

b. The bases for each design selection

c. Separable documentation for the elements of the design release baseline as required over the system life cycle

4.2.4.2 Required Attributes:

The design release baseline shall:

a. Develop the design release baseline iteratively IAW 4.2.1, 4.2.2, 4.2.3 and 4.2.5 based on tradeoffs IAW 4.2.7 and 4.2.8.

b. Develop and assess alternative solutions; identify and quantify decision criteria; and analyze decision uncertainties.

c. Perform the required functions within the limits of the performance parameters prescribed, and identify constraints and represent a balanced solution.

d. Design for interoperability.

(1) Systematically derive functionality from the operationally stated interoperability constraints.

(2) Collaborate the functional and physical interface designs and associated functions and requirements across systems.

e. Design solutions shall be based on how well the solutions meet operational Measures of Effectiveness, system Measures of Performance (MOP), and Key Performance Parameters (KPPs) along with constraints

(1) The Contractor shall ensure that Technical Performance Measures (TPMs) are established for KPPs and other risky requirements.

(2) The Contractor shall keep the MOE, MOP, KPP, TPM traceability current.

(3) The Contractor shall conduct a measurement program to measure and control requirements and design information related to each TPM.

f. Non-Developmental Items (NDI), Commercial Off-the-Shelf (COTS), preceding designs, and mature technologies shall be considered where available and selected when system technical requirements are met and the resulting solution results in the best balance of capability, cost, schedule, risk, and potential for evolutionary growth.

g. The Contractor shall identify and evaluate Open System Architectures (OSAs) where practical when they meet program requirements and are cost effective over the entire life cycle. For Automatic Information Systems (AIS), open systems architectures are mandated unless a compelling reason exists for using a proprietary architecture. If the tasking agency accepts a proprietary solution, it shall provide written justification for adopting the proprietary solution as well as a plan to migrate the system to an open systems solution at the earliest opportunity.

h. The Contractor shall identify opportunities for designing items for re-use and multiple application.

(1) Ensure that the reused item has been qualified in the conditions specified for the new application system.

i. The Contractor shall manage computer resources for system end items as an integral part of overall systems development**.**

(1) Not finalize computer hardware resource decisions until the software design demonstrates a maturity that minimizes the risk of inadequate processor throughput and memory.

(2) Not finalize software design decisions until computer hardware resource designs demonstrate a maturity that minimizes the risk of incompatibility.

(3) Address the requirements for software development tools and the software development, integration, and test environments.

(4) Ensure that software development is disciplined and an integrated part of systems engineering activities.

j. Design solutions shall include internal and external interfaces.

k. Design solutions shall include products, processes, operational concepts, configurations, and people.

l. Design solutions shall apply simplicity concepts, evaluating alternatives with respect to factors such as minimizing complexity, decreased parts count, enhanced interoperability, producibility, and logistics.

m. Design solutions shall allow for tolerances and variations in the design while still meeting needed system capabilities and system requirements.

n. Design solutions shall be traced to the allocated baseline.

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

a. The Contractor shall assess the system effectiveness, cost, schedule, risk, and growth potential for each tradeoff IAW 4.2.7, for each assessment of balance IAW 4.2.8 following each iteration of 4.2.1 through 4.2.4 and for each tradeoff of 4.2.7. Toward that end, the Contractor shall fully establish the dependency of the effectiveness measures, cost, and schedule on the system capabilities to be provided by the program.

b. The Contractor shall determine and define a means to relate TPM, the IMP, and the IMS to cost and schedule performance measurement and to identify traceability among them.

c. System/cost effectiveness analysis and assessment tasks shall be integrated into the systems engineering process to support development of life cycle balanced products and processes.

4.2.5.1 Required Products

a. Documented assessments.

b. Any reports documenting the results that are otherwise required by the contract and that shall be consistent with the decision database at the time of submission.

4.2.5.2 Required Attributes

a. Each assessment shall:

(1) Support the identification of mission and performance objectives and requirements.

(2) Support the allocation of performance to functions.

(3) Provide criteria for the selection of solution alternatives.

(4) Cite the tools, source data, and assumptions used.

(5) Quantify objectives and goals; align measurements, measurement objectives, and analyses activities with required capabilities, system technical requirements, and constraints.

(6) Isolate and focus on the elements of cost, schedule, and risk that could be affected by the factors considered in each tradeoff required by 4.2.6.

(7) Document measurements, measurement assessment results, and corrective solutions.

(8) Develop and implement an appropriate approach to prevent or handle risk causes that could result in significant harm or loss.

b. Each assessment of system effectiveness shall:

(1) Consider parameters that encapsulate the capability needed as well as the specialty functions (see 5.1) in selecting the elements most affected by the factors considered in a tradeoff.

(2) Be, to the extent practical, based on and linked to quantitative test, demonstration, or inspection data.

(3) Utilize effectiveness models, including simulations, when they contribute to the decision process. The models shall:

i. Allow parameters to be varied so that their relative, individual effect on total system performance and life cycle cost can be determined.

ii. Correlate performance characteristics allocated to system functions to parameters in the models.

(4) The models, data files, and their documentation shall be maintained, updated, and modified as required.

(5) Each version of a model or data file that impacts requirements, designs, or decisions shall be entered into the decision database.

c. Each assessment of cost shall:

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

(2) Apply methodologies that are accepted industry-wide.

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

(4) Employ simulation where cost effective IAW 5.2.2.

d. Each assessment of cost for an integrated assessment shall be conducted and updated as designated in the contract to support decisions, assessments of system cost effectiveness, and trade-off studies. In the cases of DoD and IC systems for which Independent Cost Estimates (ICEs) are required, the Government shall produce a Cost Analysis Requirements Document (CARD) or Intelligence Community Baseline Description (ICBD), as appropriate**:**

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

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

(3) Provide the bases for each estimate and relate the costs and cost bases to the cost risk for the system elements that account for 80% of the cost of each phase.

(4) 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.

(5) Identify the economic consequences of solution alternatives.

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

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

(8) Address cost and schedule risk.

e. Each assessment of schedule shall be based on quantitative historical time spans where available and applicable with any necessary assumptions explicitly stated and applied so that consistency is achieved among assessments.

f. Each assessment of risk shall:

(1) Focus on objective text descriptions identifying each risk, why and when it might occur, the possible consequences, and what is to be done to mitigate and/or monitor it.

(2) Not permit qualitative assessments such as high, moderate, or low, or quantitative risk assessments to mask the nature of the risk and the steps that would be or are now necessary to deal with it.

(3) Evaluate whether prototyping should be used IAW 5.2.1.

g. Each assessment of evolutionary growth potential shall:

(1) Identify the opportunities for establishing verifiable requirements for evolutionary growth.

(2) Estimate the effectiveness, cost, schedule, and risk impact of requiring such growth provisions.

h. Each assessment of Environmental Analysis and Impact shall be IAW 5.3.8.

4.2.6 Design or Physical Solution Verification and Validation

4.2.6.1 Physical Solution Verification

The Contractor shall verify repeatedly throughout the system's design and development to confirm that the system meets all documented requirements. The Contractor shall progressively verify that product and process designs satisfy their requirements (including interfaces) from the lowest level of the physical hierarchy up to the total system.[5] During its verification activities, the Contractor shall link any identified discrepancies with respect to the product configuration baseline, technical performance metrics, and constraints; and shall maintain these discrepancies as part of the decision data base.

5 INCOSE Systems Engineering Handbook, v2.0 July 2000, International Council on Systems Engineering Subsec. 2.3.

4.2.6.1.1 Required System Engineering Products

a. Design verification data.

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

4.2.6.1.2 Required Attributes:

a. The Contractor shall develop a System Verification Plan. The System Verification Plan shall define an efficient and complete series of tests, demonstrations, inspections, and analyses that verify 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.

b. The Contractor shall conduct a design qualification program for the system and each of its constituent products. The qualification data shall:

(1) Be acquired IAW the verification method for each requirement in the requirements and allocated baseline and each verify-to requirement in the design release baseline.

(2) Confirm that the design of the system 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) Confirm that each hardware component and each higher integration level has adequate design margin to account for the uncertainties over the life cycle

(4) Confirm (a) that all flight-critical software (i.e., that which could cause the unrecoverable loss of a mission) meets all allocated requirements during simulations that cover the possible range of each parameter and fully exercise all computational paths and decision logic; and (b) that mission-specific code and data meet all allocated requirements during simulations that cover the potential range for each parameter during the mission.

(5) Be 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.

(6) Be captured in the decision database.

c. The Contractor shall conduct a hardware acceptance verification program and a software quality assurance program. The acceptance verification data shall:

(1) Verify that each delivered hardware product, each constituent product of a delivered hardware product, and each system product that is applied 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 and/or either design release or product configuration baselines IAW the applicable verification method or verify-to requirements.

(2) Confirm 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) Provide assurance that all software products used in the production, verification, integration, or deployment of each delivered system product are identical to that which has been qualified.

(4) Provide assurance that all required software products are included in each delivery and are identical to that which has been qualified.

(5) Provide assurance that mission-specific code or data has been qualified for the planned mission and for operation with the hardware configuration delivered for the mission.

d. The product configuration baseline shall:

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

(2) Be based on planning, monitoring, decisions, and control IAW 4.2.8.

(3) Be 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) Be 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) Be validated based on objective data and through Government involvement and review IAW 4.2.9 to ensure compliance with the above attributes.

4.2.6.2 Physical Solution Validation

The Contractor shall validate the evolving physical solution. The Contractor shall, as appropriate, utilize techniques such as structured walk thoughts, mock-ups, simulations, and operational testing to ensure that the system, when completed, will satisfy stakeholders' requirements. The purpose of

system validation is to provide objective evidence that the services provided by the system, when the system is used as intended, comply with stakeholders' expectations.

4.2.6.2.1 Required System Engineering Products

System validation plan and data to include inputs to Operational Safety, Suitability, and Effectiveness (OSS&E)/Space Flight Worthiness (SFW) Certification, System Readiness Reviews and Initial Operational Test and Evaluation (IOT&E) support.

4.2.6.2.2 Required Attributes

a. The Contractor shall define in detail and document the validation process it intends to follow pursuant to the system validation process. The validation plan shall detail the efforts to be performed by the Contractor to ensure that the system meets stakeholder expectations. In particular, it shall:

   (1) Identify the various stakeholder groups, including points of contact, from which feedback will be sought.

   (2) Detail plans to convene Stakeholders' and Developers' Forums, as well as the agenda for these Forums, so that stakeholders can be informed of and given feedback opportunities regarding the evolving work products and operational architecture.

   (3) Identify any computer and other resources needed for such efforts as well as any needed Government-Furnished Equipment (GFE) and Government-Furnished Information (GFI).

   (4) Detail plans for modeling and simulation in conjunction with the validation effort, including human-in-the-loop simulation.

b. The Contractor shall construct a system model pursuant to its validation of the product configuration baseline and metrics. This model shall:

   (1) Be as detailed as is appropriate, given the available time and other resources as well as the granularity of information available at the time.

   (2) Include a representation of all physical devices that have been identified thus far in the Synthesis step of the systems engineering process.

   (3) Be refined in subsequent iterations of the design effort.

c. During its validation activities, the Contractor shall document any discrepancies between the:

(1) Product configuration baseline and stakeholder expectations

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

d. The Contractor shall document any validation process findings and lessons learned in a format suitable for incorporation into the operational test plans.

e. The Contractor shall provide inputs to the 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.

(1) The Contractor shall provide support to the System OSS&E Incremental Reviews to include SFW criteria assessments.

f. The Contractor shall provide support to the System Readiness Reviews to include the Mission Readiness Review, Flight Readiness Review, and the Post Flight Reviews.

g. The Contractor shall prepare for and support IOT&E to include:

(1) Planning for and conduct of developer support for IOT&E captured in the IMP/IMS and EVMS.

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

(3) 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.

(4) Delivery of validated requirements for Government-inventory (common) support equipment in time for their availability prior to the start of IOT&E.

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

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

(7) Planning for developer support during IOT&E, including the timely resolution of observed anomalies or deficiencies.

4.2.7 Tradeoff Analyses

Tradeoffs shall be identified, organized, planned, and conducted to compare the capability or effectiveness, life-cycle cost, schedule, and risk implications of each promising alternative addressed within each iteration of 4.2.1 through 4.2.6.

4.2.7.1 Required System Engineering Products

Documented trade-off analyses.

4.2.7.2 Required Attributes

a. Be planned and conducted to objectively compare assessments of system effectiveness, life-cycle cost, schedule, risk, and evolutionary growth implications IAW 4.2.5 for each feasible alternative requirement, functional decomposition, allocation, and/or design selection for each iteration through part or all of 4.2.1 through 4.2.5 (through 4.2.6 when developed system products are available).

b. For communications, command, or control links between geographically separated nodes of the system or between the system and other systems to specifically include those links addressed in the Technical Standards View-1 (TV-1) of the integrated architecture for interoperability, including applicable standards in the current version of the Joint Technical Architecture (JTA) in the alternatives traded.

c. For both the plans and the results, be captured in the decision database.

4.2.8 Management of the Systems Engineering Process

The Contractor shall manage the work required to satisfy 4.2.1 through 4.2.7 through the integration of the technical effort including planning, monitoring, decision making and control, risk management, configuration management, interface management, and data management of the products developed, as well as commensurate flow down of requirements and technical management of subcontractors and vendors.

4.2.8.1 Planning

The developer shall plan the work herein.

4.2.8.1.1 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).

c. Such other specific plans (such as tradeoff plans) as may be needed to achieve the attributes required above.

d. Systems Engineering Management Plan (SEMP) if and as otherwise required by the contract.

4.2.8.1.2 Required Attributes:

For each application of this standard, the Contractor shall:

a. Integrate all technical execution and management efforts in accordance with the systems engineering process. The integrated technical effort shall:

(1) Be integrated to yield a single and complete process that focuses all activities on satisfying the technical requirements of the contract.

(2) Reflect all technical execution and management efforts in the integrated Master Plan (IMP), Integrated Master Schedule (IMS), and the Systems Engineering Management Plan (SEMP), if otherwise required by contract.

(3) Extend and maintain the Contract Work Breakdown Structure (CWBS) consistent with the evolving physical architecture or design solution and apply it to plan and monitor all work carried out under the contract.

b. The contractor shall develop the IMP (exclusive of the IMP narrative), SEMP, IMS, EVMS, and other plans that:

(1) are structured to implement the results and decisions from any previous contractual phases, and to include the technical reviews and audits that are applicable to the contract phase as events in the IMP.

(2) are structured to measurably define the extent and depth of the work, the resulting products, and the decisions for each iteration IAW 4.2.1, 4.2.2, 4.2.3, 4.2.4, 4.2.6, and 4.2.8.

(3) are structured to implement the risk monitoring and mitigation steps that have been identified.

(4) Scope the tradeoff analyses required herein to be conducted IAW 4.2.7 to:

(a) Identify the factors or parameters to be traded; the elements of effectiveness, cost, schedule, risk, and evolutionary growth to be assessed; the source data that are to be the basis of the assessments; the tools or development environments to be applied; the assumptions; and the schedule;

(b) Organize the tradeoffs for orderly decision making (such as in a decision tree), and

(c) Identify the potential decisions and resulting implementation steps (such as baseline changes and risk mitigation actions).

(5) Scope the assessments required IAW 4.2.5 to identify tools (to include development environments including software and hardware in the loop if planned), assumptions, schedule, and potential decisions and resulting implementation steps.

(2) Plan and organize the verification program and support to validation IAW 4.2.6 to minimize the cost and schedule for completion.

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

c. The IMP Narrative shall describe and commit to the processes, tools, and development and evaluation environments necessary to complete each systems engineering product required herein to specifically include those that are to be the basis for each decision and the implementation actions that follow from the decision.

d. The SEMP, if otherwise required by the contract, shall be logically linked to and extend the description and commitments in the IMP Narrative.

4.2.8.2 Monitoring

The Contractor shall monitor the progress against all planning herein 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 or mitigate each risk.

e. Capture the results in the decision database.

4.2.8.2.1 Required System Engineering Products

Each assessment linked in the decision database to the iteration of which it is a part and to the decision it supports.

4.2.8.2.2 Required Attributes

The Contractor shall:

a. Monitor all integrated assessments of system effectiveness, schedule, life-cycle cost, risk (to include the status of the risks on the watch list), including progress against the plans (IMP, IMS, and EVMS) and evolutionary growth IAW 4.2.5 as follows:

   (1) Provide program status relative to the plans in the IMP, IMS, EVMS, and specific plans, and estimates of the instant contract cost and schedule at completion for each technical review IAW 4.2.9.

   (2) The assessments of the verification data (when developed products are available) shall ensure effective identification, disposition, and control of deficiencies and non-conformances.

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

   (4) Include all risks, including those identified by the assessments IAW 4.2.5, which are designated to be monitored as part or all of the selected mitigation approach.

   (5) Identify the TPMs, metrics, and/or renewed risk assessments for monitoring each risk, and describe the methodology, tools, and schedule for assessing each.

      (a) Establish metrics update frequencies, tracking depth, and, response time to generate recovery plans and planned profile revisions, when otherwise not provided.

      (b) Select technical parameters for tracking that are critical indicators of technical progress and achievement and shall include either system parameters, CI parameters, or both.

   (6) Collect data in support of the metrics program. The SEMP should identify the specific points of contact responsible for data collection along with the procedures to be used and the frequency with which the data will be collected.

b. Capture the results in the decision database.

4.2.8.3 Decision Making, Control, and Baseline Maintenance

In accordance with 4.2.5.1.2 above, the Contractor shall decide on and implement the actions necessary 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.

4.2.8.3.1 Required System Engineering Products

a. Documented and implemented decisions.

b. Maintained baselines and functional architecture.

4.2.8.3.2 Required Attributes

Decisions as the result of the work required herein shall:

a. Be made when the monitoring required above indicates the need for corrective action so as to meet contract requirements while minimizing contract cost and schedule impacts.

b. Be made for each iteration IAW 4.2.1, 4.2.2, 4.2.3, 4.2.5, and 4.2.6 and each design selection IAW 4.2.4 toward achieving the baseline attributes required in 4.2.1 through 4.2.4.

c. Be explicitly related to the tradeoffs carried out IAW 4.2.7 and assessments conducted IAW 4.2.5 or other objective analyses or monitoring data.

d. Be 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.

e. Be captured in the decision database.

4.2.8.4 Risk Management

The Contractor shall establish and implement a risk management program. Risks shall be assessed for products, processes (e.g., process variability), and their interrelationships. Risk shall also be assessed for contractually identified variations, uncertainties, and evolutions in system environments.

4.2.8.4.1 Required Products

Risk watch list.

4.2.8.4.1.1 Required Attributes

The Risk Management Program shall be conducted for each iteration IAW 4.2.1 through 4.2.6 to:

a. Identify potential sources of technical risk including critical parameters that can be risk drivers.

b. Quantify 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. Include design, cost, and schedule uncertainties and sensitivity to program, product, and process assumptions.

c. Determine the activities and criteria for identifying, assessing, validating, and transitioning critical technologies from technology development and demonstration programs, including commercially developed technologies.

(1) Include maturity in performance, affordability, and life cycle processes in the criteria.

d. Determine sensitivity of interrelated risks.

e. Determine alternative approaches to handle moderate and high risks.

f. Take actions to avoid, control, or assume each risk.

g. Establish a process for continued identification of risks throughout the program life cycle.

h. Ensure that risk factors are evaluated as a part of decision-making including the selection of specification requirements, and design and solution alternatives.

i. For COTS-intensive programs, the Contractor shall address how technology refresh shall be accomplished.

4.2.8.5 Baseline Change Control and Maintenance

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.

4.2.8.5.1 Required System Engineering Products

Assessments of Change Control Implementation.

4.2.8.5.2 Required Attributes

Assessments of change control implementation shall:

a. Include the decisions and change control actions to develop the baselines and the functional architecture IAW the requirements herein, maintain them in consonance, and achieve contract cost and schedule targets or objectives.

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

(1) Change control shall explicitly assess each proposed change to a baseline or functional architecture:

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

(b) To determine 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.

(2) Change control shall, for changes that could affect completed product verifications or approved product configuration baselines, plan and conduct new verifications, and record the results in the decision database.

(3) Relate the basis for the proposed change to these assessments to determine whether the proposed change is justified.

(4) Achieve agreement and approval by both development managers for each affected system and systems engineering product and a development manager having responsibility for all affected products.

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

(6) Provide for monitoring the status of implementing all approved changes.

(7) Provide recommendations, accompanied by the impact analysis and product manager agreements and approvals, to the Government to maintain the approved baselines for which the Government retains control and then complete the related change actions upon receipt of the Government decision.

(8) Determine changes that could affect completed product verifications or approved product configuration baselines, plan and conduct new verifications, and record the results in the decision database.

(9) Corrective Action Plans shall be captured in the decision database

c. Respond to ad hoc queries and allow for searching, using standard search engines, regarding CM issues from users authorized to access the Automatic Information System.

d. Capture the results in the decision database.

4.2.8.6 Interface Management

The Contractor shall manage the internal interfaces within their contractual responsibility, and shall support activities established to ensure that external interfaces are managed and controlled.

4.2.8.6.1 Required System Engineering Products:

Interface control documents and drawings.

4.2.8.6.2 Required Attributes

For each iteration of 4.2.1 through 4.2.6 the Contractor shall:

a. Establish, coordinate, and maintain interface controls for interface requirements, documents, and drawings, and include all applicable Contractor, vendor, and subcontractor contract items and Government-furnished equipment, computer programs, facilities, and data.

b. Control interfaces to ensure accountability and timely dissemination of changes.

c. Capture all changes to the internal and external interfaces in the decision database.

d. Ensure that all interface requirements are verified.

4.2.8.7 Data Management

The Contractor shall establish and maintain an integrated data management system.

4.2.8.7.1 Required System Engineering Products

Data Products as required by the contract and to support the program.

4.2.8.7.2 Required Attributes

The integrated data management system shall provide data to the decision database to:

a. Capture and organize all inputs ,as well as current, intermediate, and final outputs.

b. Provide data correlation and traceability among requirements, designs, solutions, decisions, and rationale.

c. Document engineering decisions, including procedures, methods, results, and analyses.

d. Be responsive to established configuration management procedure.

e. Function as a reference and support tool for the systems engineering effort.

f. Make data available and sharable as called out in the contract.

4.2.8.8 Technical Management of Subcontractors/ Vendors

The developer shall flow the requirements herein 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 to include a seamless link with the applicable elements of the decision database.

The developer shall 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.

4.2.8.9 Lessons Learned and Continuous Improvement

The developer shall document lessons learned from implementing the process chosen to meet the systems engineering requirements herein in the decision database followed by timely and effective improvement. The developer shall notify the Government of issues with or potential improvements to this document.

4.2.9 Application Across The Life Cycle

The system engineering process addressed in this standard shall be applicable throughout the system life cycle. Moreover, it shall be applicable for systems being acquired via a traditional waterfall acquisition as well as those being acquired using evolutionary acquisition techniques. Outputs of the systems engineering effort are acquisition phase dependent. The developer shall plan and implement a staged development across the system life cycle focused on validating, during technical reviews and audits, the decisions made to achieve increasing maturity in the baselines. Technical reviews and audits shall be planned and conducted IAW MIL-STD 1521C.

4.2.9.1 Required System Engineering Products

The close-out of each technical review and audit, including resolution of all action items from the review.

4.2.9.2 Required Attributes

The technical reviews and audits shall**:**

a. Include over the set of contract phases making up each evolutionary spiral, increment, modification, or upgrade:

(1) The Alternative Systems Review (ASR).

(2) The System Requirements Review (SRR).

(3) The System Preliminary Design Review (PDR).

(4) The System Critical Design Review (CDR).

(5) One or more Functional Configuration Audits (FCAs) to collectively address each component and separately qualified integrated grouping of components.

(6) The System Verification Review (SVR).

(7) One or more Physical Configuration Audits (PCAs) to collectively address each component and separately qualified or verified integrated grouping of components.

(8) Test Readiness Reviews (TRRs)

(9) IOT&E Readiness Review.

b. Be planned IAW 4.2.8 and conducted:

(1) To achieve the baselines status required in Table 4.1 with the terms designating the required baseline maturity taken as follows.

(a) Preliminary – the result of one or more iterations during each contractual phase through the systems engineering steps required by 4.2.1, through 4.2.5.

(b) Draft – the result of one or more additional iterations beyond those to achieve the preliminary results and of a review that demonstrates readiness to be approved at the next technical review.

(c) Approved – The description of the maturity of requirements, , design release, or product configuration baseline that (a) has been validated IAW the requirements herein, and (b) as a step in the close out of the indicated review, has been placed under formal configuration management IAW the baseline maintenance requirements herein and any other contract configuration management requirements.

(d) Maintained – Description of the maturity of a baseline that has been previously approved and in which all changes to the technical requirements and constraints, functional flows and allocations, or system products have been reflected IAW the requirements herein and any other contract configuration management requirements.

(2) Such that the functional architecture achieves the same state of maturity and is maintained the same as the allocated baseline except that it is not formally approved.

(3) Such that the product configuration baseline:

(a) Is initially approved for any system products that are manufactured, coded, procured, or integrated during a development phase and that are to be used for operations to provide residual operational capability, or to provide a baseline for continued development in the next evolutionary spiral or increment.

(b) Is initially approved for other system software products no later than delivery for operations.

(c) Is initially approved for other system hardware products that are subject to production using full-rate-production representative hardware.

(d) Is maintained through Delta PCAs held to ensure that each change has been qualified and that the verified system product continues to be represented by the baseline.

(4) Such that the Test Readiness Reviews (TRR) demonstrate readiness of the test planning and test procedures, the product(s) under test, and any required support equipment prior to each qualification test, demonstration, or inspection (or group of such events).

(5) Such that the IOT&E Readiness Review demonstrates compliance with the applicable requirements of 4.2.6 prior to the start of T&E.

c. Be supported by a review data package and technical reports that, based on and strictly consistent with the data in the decision database, show compliance with the requirements herein to include the validation of any baseline presented for approval or the maintenance of any approved baseline (and the functional architecture if the allocated baseline has been approved) and report the status of each baseline and the functional architecture relative to the requirements of Table 4.1, the results of the tradeoffs IAW 4.2.7 and resulting iterations IAW 4.2.1 through 4.2.5. (through 4.2.6 when developed system products are available), the assessment of balance IAW 4.2.5, and, except for the FCA and PCA, the integrated assessment IAW 4.2.8.

d. Include confirmation of readiness to proceed toward the next IMP event to include satisfaction of all significant accomplishment criteria for the current event and the planning, monitoring devices, equipment, facilities, and personnel needed to achieve the next event.

e. Be formally closed out by acceptance by the customer of the response to any action items and by completing any applicable baseline approval IAW Table 4.1 and other requirements herein.

Table 4.1. Development Stages for increasing accuracy and completeness of the program baselines

Nominal DoDI 5000.2 Phase[6]	**Nominal NSSAP 03-01 Phase**	**Technical Review or Audit**	**Required Maturity of the Baselines**			
			Requirements	**Allocated**	**Design Release**	**Product Configuration**
Concept Refinement	Pre-KDP	ASR	Preliminary, focus on support to JCIDS	Preliminary, focus on physical elements which drive cost, risk, and other considerations	Preliminary – basis for support to capability needs process and for concept refinement	–
Technology Development	A	SRR	Draft which balances system effectiveness, cost, schedule, risk, and growth potential	Preliminary, focus on physical elements which drive risk or other considerations	Preliminary – reflects concept refinement and basis for technology maturation and other risk reduction	–
	B	SDR	Approved IAW a.a(6)	Draft which balances system effectiveness, cost, schedule, risk and growth potential	Preliminary – basis for technology selection and for the assessment to support requirements baseline validation	–

6 The nominal acquisition phases in DoDI 5000.2 or **NSSAP 03-01** are listed only to anchor the required baseline maturity approximately in the life cycle—the title and objectives for the contractual phase as defined in the RFP or contract **shall** take precedence.

Nominal DoDI 5000.2 Phase[6]	Nominal NSSAP 03-01 Phase	Technical Review or Audit	Required Maturity of the Baselines			
			Requirements	Allocated	Design Release	Product Configuration
System Integration		PDR	Maintained	Approved IAW 4.2.2	Draft – basis for assessment to support allocated baseline validation	–
		CDR	Maintained	Maintained	Approved IAW 4.2.4 build, buy, code, author, and integrate devel-opmental system products for qualification	–
System Demo	C	FCA	Maintained	Maintained	Maintained	–
		SVR	Maintained	Maintained	Maintained	–
Production and Deployment		PCA	Maintained	Maintained	–	Approved and subsequently maintained

4.3 Systems Engineering Output

The Contractor's system engineering process shall, in concert with the program management and other processes, produce the products required for each of the program milestones per the appropriate acquisition guidance. These products shall be produced sufficiently prior to each of the program milestones so that the Milestone Decision Authority can have adequate time to review them prior to the program milestone.

The Contractor shall develop implement and maintain a decision database, the required system and subsystem specifications, baselines and life cycle support data.

4.3.1 Decision Database

4.3.1.1 Required Attributes

The developing activity shall develop and maintain a decision database. The Decision Database shall:

a. Meet the requirements herein.

b. Document and organize data used and generated by the systems engineering effort.

c. Provide an audit trail of results and rationale from identified needs to verified solutions for traceability of requirements, designs, decisions, and solutions.

d. Provide a chronological track with links to the initial plans, the results of each iteration IAW 4.2.1 through 4.2.6 to include the tradeoffs and other assessments, the decisions made, their justification, the actions taken including revised plans or changes to the base-lines or functional architecture proposed or made as a result of the decisions.

e. Provide two-way traceability between, as they evolve, the capability needs and other Government source data to the elements of the requirements baseline to the elements of the functional architecture to the elements of the allocated baseline to the elements of the design release or product configuration baseline, i.e., from mission needs down to capabilities, architecture, requirements, specifications, and physical devices or software modules; and, from physical devices or software modules upward to specifications, requirements, architecture, capabilities, and mission need.

f. Provide two-way links between, as they evolve, each CWBS element and each product; between each product and the associated elements of the baselines and functional architecture; between each element of the baselines and functional architecture, on the one hand, and its change history including the justification and authorization for each change, on the other hand; and between each element and its validation and verification methods, plans, procedures, and results.

g. Be maintained over the life of program.

h. Include an archived image of the data at the time of the close out of each technical review and audit IAW 4.2.9.

i. Be readily available to and directly accessible by the Government.

4.3.2 Specifications and Baselines

The Contractor shall generate required system and configuration item (CI) specifications and baselines and documentation.

4.3.2.1 Required attributes

The Contractor shall:

a. Progressively develop the documentation used to establish configuration baselines (Functional, Allocated, Design Release, and Product).

b. Formalize the specifications to establish configuration baselines commensurate with the contracted effort.

c. Document, control, and audit configuration baselines in accordance with contractual configuration management practices.

d. Include essential requirements for processes in item specifications.

e. Ensure that specification requirements are verifiable. Traceability to their verification criteria and methods shall be maintained.

f. Present specifications for approval by the Government only when:

(1) The cost, schedule, and performance risks associated with the item and its processes have been determined and the risk levels are acceptable;

(2) Item costs have been determined and those costs satisfy established design-to-cost targets or other prescribed affordability limits; and

(3) Its completeness and design attainability have been confirmed.

g. Ensure that system functional and CI development specifications are performance based.

h. Identify, annotate, and track those elements in the decision database necessary for the life cycle management of the system.

4.3.3 Requirements Traceability Matrix

The Contractor shall develop a requirements traceability matrix.

4.3.3.1 Required Attributes

The traceability matrix shall:

a. Be an extension and update to or otherwise traceable to any similar matrix or other data in the Systems Engineering Program Foundation and be consistent with decisions by the Government program decision authorities.

b. Provide downward traceability of capabilities and mission requirements to technical requirements, specifications, and physical products.

c. Provide downward traceability of capabilities and mission requirements to technical requirements, specifications, and physical products.

d. Be able to perform full upward or downward traceability from any level of the traceability tree.

e. Be instantiated on the Contractor's automated information system and support real-time traceability queries.

f. Be compatible with standard project management, database, data mining, and related software products.

g. Be included in the Decision Data Base.

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5. Detailed Requirements

This section describes systems engineering tasks that shall be evaluated/tailored for integrating product and process development as applied to a specific program and phase. Tailored requirements for program-specific tasks will be provided by the Government in solicitations or suggested by the Contractor through procedures such as responses to draft request for proposals.

5.1 Functional Tasks (Specialty Functions)

The tasks listed below do not preclude or supersede tasks applied from other standardization documents. The Contractor shall**:**

a. Ensure that the following tasks are incorporated into the systems engineering process.

b. Include these tasks in the requirements analysis, functional analysis/allocation, synthesis, and systems analysis and control.

c. Include their impact in system life-cycle cost estimates.

These tasks reflect important areas in system development. The determining factor for the degree of performance required shall be satisfying total system cost, schedule, and performance requirements and objectives, at an acceptable level of risk.

5.1.1 Integrated Logistics Support (ILS)

The Contractor shall identify and define functional and performance requirements and derive solution-dependent requirements to ensure that items are supportable. The Contractor shall:

a. Ensure that requirements are related consistently to readiness objectives to design and to each other;

b. Integrate support factors into item and system element design interactively with the design of support products and processes;

c. Identify cost-effective approaches to supporting an item when deployed/installed;

d. Identify and define requirements for support structure elements so that the item is both supportable and supported when deployed/installed; and

e. Plan for post-production support to ensure continued, economic logistics support.

5.1.2 Manufacturing/Producibility

The Contractor shall identify and define functional and performance requirements and derive solution-dependent requirements for producibility.

5.1.2.1 Required System Engineering Products

Manufacturing trades, analyses, and plans linked in the decision database to the manufacturing instructions, processes, or other information that they support or justify.

5.1.2.2 Required Attributes

The Contractor shall:

a. Ensure that items are producible and that stable manufacturing processes are in place to reduce risk, manufacturing cost, lead time, and cycle time; and that minimize use of strategic and critical materials.

b. Define, evaluate, and select, as part of system design, manufacturing methods, processes, and process controls based on total system cost, schedule, performance, and risk.

   (1) Prior to full rate production, the Contractor shall ensure that the product design has stabilized, the manufacturing processes and process controls have been proven, and rate production facilities, equipment, capability, and capacity are in place (or are about to be put in place) to support the approved schedule.

c. The Contractor shall use value engineering concepts to assist in the identification of requirements that add cost to the system but add little or no value.

5.1.3 Parts, Materials, and Processes (PMP) Control.

The Contractor shall establish and implement a parts, materials and processes (PMP) control program.

5.1.3.1 Required System Engineering Products

a. PMP Control Plan

b. Studies, analyses and decisions relating to PMP linked in the decision database to the iteration of which they are a part and to the assessments or design and other decisions they support or justify.

5.1.3.2 Required Attributes

The PMP program shall**:**

a. Focus on standardization of parts, materials, and processes.

b. Addresses the design, procurement, and availability of parts through the expected life of each item, the environment that the item is required to operate in, and account for life-cycle support costs.

c. Emphasize reducing the variety of parts, variability in processes, and associated documents used with items.

5.1.4 Quality Assurance

The Contractor shall establish a Quality Assurance (QA) program to verify and validate that the product development process is complete, in compliance with requirements, and meets customer expectations. These assurance processes embrace nearly the complete product acquisition life cycle.

5.1.4.1 Required System Engineering Products

a. Quality Assurance Plan.

b. All QA analyses, studies, decisions etc. linked in the decision database to the iteration of which they are a part and to the assessments or decisions they support or justify.

5.1.4.2 Required Attributes

The quality assurance management process shall include:

a. Establishment of capable processes

b. Monitoring and control of critical processes and product variation

c. Establishment of mechanisms for feedback of field performance

d. Implementation of an effective root cause analysis and corrective action system; continuous process improvement

e. The means to assure disciplined control over the design, procurement, manufacturing, integration, and test processes

f. Quality Assurance schedules that are established that concurrently support procurement, manufacturing, integration, and test processes

g. Quality Assurance policies and procedures in place to manage internal and external production sources

h. A means in place to ensure early detection and correction of manufacturing processes that deviate beyond accepted limits

5.1.5 Reliability and Maintainability

The Contractor shall identify and define functional and performance requirements and derive solution-dependent requirements to ensure that items are reliable and maintainable.

5.1.5.1 Required System Engineering Products

Reliability and maintainability analyses and studies linked in the decision database to the iterations of which they are a part and to the assessments or decisions they support.

5.1.5.2 Required Attributes

The Contractor shall place emphasis on:

a. Determining requirements based on the user's system readiness and mission performance requirements, physical environments, and resources available to support the mission;

b. Managing the contributions to system reliability and maintainability made by system elements;

c. Preventing design deficiencies (including single-point failures), precluding the selection of unsuitable parts and materials, and minimizing variability effects in manufacturing processes;

d. Developing robust systems, acceptable under specified adverse environments experienced throughout the system's life cycle and repairable under adverse conditions; and

e. Developing items that have low impact on support resources including time, people, money, parts, tools, storage, and transportation assets.

5.1.6 Survivability

The Contractor shall identify and define functional and performance requirements and derive solution-dependent requirements to ensure that items are survivable when those items must perform critical functions in hostile environments. The Contractor shall identify and define a survivability program or a continuity of operations plan, as appropriate for the system being developed.

5.1.6.1 Required System Engineering Products

a. Survivability management plan.

b. Survivability analyses linked in the decision database to the assessments or decisions they support or justify.

c. Continuity of operations planning documents, per standard business continuity planning.

5.1.6.2 Required Attributes

The Contractor shall:

a. Analyze survivability from all possible sources of threats found in the natural and operating induced environment and in specified levels of conflict. Threats to be considered include, but are not limited to, rain; thunderstorm; hurricane; sand and dust; snow; solar radiation; temperature; humidity; pressure; high-saline atmosphere; earthquake; transient dynamics; random vibrations; natural radiation; conventional, electronic, nuclear, biological, chemical, high-power microwave, kinetic energy, and directed energy weapons; and terrorism or sabotage. Identify, assess, and evaluate critical survivability characteristics for their impact on system effectiveness.

b. Develop hardness assurance, hardness maintenance, and hardness surveillance programs for items hardened to meet a survivability requirement in order to identify and correct procedures in manufacture, repair, spare parts procurement, and maintenance or repair activities that may degrade item hardness during the system's life cycle for items hardened in order to meet a survivability requirement.

c. Continuity of operations shall be developed in the context of business continuity planning, and not necessarily entail the total duplication of infrastructure, software, and data.

5.1.7 Environmental, Safety and Health (ES&H)

The Contractor shall develop and implement a thorough and comprehensive ES&H program. The Contractor shall identify and define functional and performance ES&H requirements and derive solution-dependent requirements consistent with higher-level and mission requirements as well as cost effectiveness to effect safe use of system items and to control safety and environmental hazards associated with system items.

5.1.7.1 Required System Engineering Products

a. Programmatic Environmental, Safety and Health Evaluation (PESHE) report if and as otherwise required by the contract.

b. ES&H analyses linked in the decision database to the iteration of which they are a part and to the assessments and decisions they support or justify.

5.1.7.2 Required Attributes:

The Contractor shall**:**

a. Identify significant program ES&H risks and implement corrective actions and alternatives to eliminate or reduce environmental, health, and identified hazards and unsafe conditions, plus the threat of regulatory violations.

b. Identify Programmatic Environmental, Safety and Health Evaluation (PESHE) requirements.

c. Analyze the total system of people, products, and processes, including verification, manufacture, support, and disposal activities, to identify potential hazards for the life cycle.

d. Define the required interfaces with other functions to ensure orderly and effectual integration of the tasks performed.

e. Establish environmental compliance, pollution prevention, hazardous material management, and the National Environmental Policy Act (NEPA) requirements.

f. Set criteria for monitoring and reporting of pollution elimination/reduction efforts.

g. Document identified hazards associated with use of system end items to establish criteria for mitigating or defining and categorizing high and serious risks.

h. Characterize materials categorized as having high and serious risks in terms of risks related to producing, deploying, operating, supporting, training with, and disposing of system end items using such materials.

i. Avoid use of materials that present a known hazard to the extent practical. If use of hazardous materials is an essential element of the solution,

j. Develop and implement a containment program, including procedures for safe use and disposal. This program shall include eventual substitution for hazardous materials except for those explicitly accepted by the Government for the specific application.

k. Include handling and disposal of hazardous material in life-cycle cost estimates.

5.1.8 Mass Properties

If appropriate for the system being developed, the Contractor shall develop and implement a Mass Properties Control Plan and a Mass Properties Verification Plan with the objective of meeting the mass properties requirements of the program.

5.1.8.1 Required System Engineering Products

Mass Properties Control Plan if and as otherwise required by the contract.

5.1.8.2 Required Attributes

The Contractor shall:

a. Establish and maintain mass properties objectives and provide planning and execution of mass properties control functions.

b. Determine, control, and document the mass properties of the system, subsystems, and components.

c. Define the interfaces with other functions to assure that all system requirements are met.

d. Implement the mass properties control plan, including tracking limits against projected mass properties.

e. Document the mass properties control and determination and test procedures and verification tests in the decision database linked to the elements of the requirements, allocated, design release, and/or product configuration baselines to which they relate.

5.1.9 Human Factors

The Contractor shall develop and implement a comprehensive management and technical strategy for human systems integration with the objective of establishing acceptable compatibility between the system and the people who operate, maintain, and support it.

5.1.9.1 Required System Engineering Products

Human Factors Support Plan.

5.1.9.2 Required Attributes

The Contractor shall:

a. Plan and implement a human factors engineering program to ensure the satisfaction of system objectives and safety of the operator, maintainer, and support personnel.

b. Integrate human systems integration considerations into the system engineering approach to the simultaneous design of the product and its manufacturing, test, and support processes to ensure that system objectives are met and personnel safety is considered.

c. Implement human factors engineering as an integral part of the systems engineering process and closely align with the other disciplines of reliability, maintainability, safety, environmental, producibility, test, and electromagnetic compatibility.

d. Identify and eliminate program risks associated with critical human factors that have a significant impact on readiness, life-cycle costs, schedule, performance, or safety.

e. Ensure that manpower, personnel, training, and logistics support information is derived as soon as feasible so that human factors engineering principles and solutions can be applied in a cost-effective and timely manner to the design effort. Identify and define functional and performance requirements and derive solution-dependent requirements to ensure that human factors are integrated into product and process designs.

f. Objectives shall include balance of system performance and total cost of ownership by ensuring that item designs are compatible with the capabilities and limitation of the personnel who will operate, maintain, transport, supply, control, and dispose of the items.

g. Requirements and designs shall minimize characteristics that: require extensive cognitive, physical, or sensory skills; require the performance of unnecessarily complex tasks; require tasks that unacceptably impact manpower or training resources; or result in frequent, repetitive, or critical errors.

5.1.10 Electromagnetic Compatibility and Radio Frequency Management

If appropriate for the system being developed, the Contractor shall develop and implement an Electromagnetic Control Program that will assure that the system meets all electromagnetic compatibility requirements.

5.1.10.1 Required System Engineering Products

Electromagnetic Control Plan.

5.1.10.2 Required Attributes

The Contractor shall:

a. Describe the proposed EMI/EMC criteria to be used in the design of the system, the testing requirements for development, qualification, and verification to assure the end product meets the contract and technical performance requirements.

b. Identify and define functional and performance requirements and derive solution-dependent requirements to ensure that system solutions employing electric and electronic items can achieve necessary performance in intended environments.

c. Ensure that electric and electronic items comply with applicable DoD, national, and international electromagnetic compatibility requirements.

d. Ensure that intentional radiators or receivers of radio frequency energy comply with DoD, national, and applicable international policies for radio frequency spectrum management.

5.1.11 System Security

The Contractor shall develop and implement a System Security Program.

5.1.11.1 Required System Engineering Products

System Security Management Plan. Documents system security engineering process.

5.1.11.2 Required Attributes

The Contractor shall**:**

a. Discover Protection Needs. Identify mission assets. Assess threats to those assets.

b. Define System Security Requirements. Ensure system security requirements address system specific threats and comply with applicable DoD, national, and international system security policy.

c. Design System Security Architecture. Concurrently develop system security architecture with the system architecture.

d. Develop Detailed Security Design. Analyze constraints and trade-offs. Coordinate cryptography plans with the National Security Agency.

e. Implement System Security. Examine system security issues and provide inputs to certification and accreditation process activities.

f. Assess System Protection Effectiveness. Verify that protection mechanisms satisfy security requirements. Ensure that residual security risks have been approved by appropriate authorities (DoD, national, and international approving authorities).

5.1.12 Test and Evaluation

The Contractor shall plan, develop, and implement a Test and Evaluation capability to efficiently and effectively define the detailed test requirements, plan the approach required to accomplish the requirements, control the work performed, and identify and manage the associated risks.

5.1.12.1 Required System Engineering Products

a. Test Plans and procedures resident in the decision database.

b. Test Reports linked in the decision database to each requirement that is verified or otherwise addressed by the test and to the test plans and procedures that were implemented in the test.

c. Any test scripts or software produced in support of the test activity linked to the test in the decision database.

5.1.12.2 Required Attributes

The Contractor shall**:**

a. Identify and define functional and performance requirements and derive solution-dependent requirements to ensure that all required item characteristics are verifiable.

b. Integrate the verification of the acceptability and compatibility of human performance requirements, personnel selection, training, and man-machine interfaces of system procedural data into the system test program. The objectives, scope, and type of system test and evaluation shall reflect an integrated approach for functionality verification to conserve resources.

c. Conduct test and evaluation planning that addresses performance, functional, and design requirements with appropriate quantitative criteria, test events or scenario descriptions, resource requirements (e.g., test range, special test facilities), and test limitations. Wherever practicable, tests for different objectives shall be combined.

d. Conduct test and evaluation efforts structured to:

(1) Provide information for assessment of technical risks and for decision making;

(2) Generate information to determine whether items have met technical performance requirements, specifications, and objectives;

(3) Verify that items are operationally effective and suitable for intended use;

(4) Verify the critical assumptions, data, and methods used to derive critical item requirements (e.g., safety, survivability, electromagnetic compatibility); and

(5) Verify the critical assumptions, data, and methods used in the verification of item performance.

5.1.13 Infrastructure Support

The Contractor shall identify and define functional and performance requirements for a compatible interface with the infrastructure supporting the system.

5.1.13.1 Required System Engineering Products

Infrastructure support requirements linked in the decision database to the iteration of which they are a part and to the analyses that support or justify the requirements.

5.1.13.2 Required Attributes

The Contractor shall**:**

a. Derive solution-dependent requirements for a compatible interface with the infrastructure supporting the system.

b. Identify unique infrastructure support requirements and ensure timely planning to provide needed infrastructure support.

c. Assess each item for its interaction with and integration into the command, control, communications, and intelligence structure.

d. Identify the support that the system will require from other support agencies and commands (e.g., mapping, charting, geodesy, and meteorology).

5.1.13.3 Required System Engineering Products

Reports documenting infrastructure support requirements and linked in the decision database to the iteration of which they are a part and to the analyses that support or justify the requirements.

5.1.14 Other Functional Areas

The Contractor shall identify and define other areas of the system's functionality to derive and define additional system requirements needed to satisfy higher level requirements. As the functionality of the system is defined during execution of the systems engineering process, additional functional tasks may also be identified. An example is resource conservation (e.g., life-cycle resources, energy consumption, preservation of material for recycling).

5.2 Pervasive Development Considerations

The following tasks, as selected and tailored for the particular program application, shall be integrated into the systems engineering process.

5.2.1 Prototyping

The Contractor shall evaluate whether prototyping should be used to assist in identifying and reducing risks associated with integrating available and emerging technologies into an item's design for satisfying requirements.

5.2.1.1 Required System Engineering Products

Evaluations of prototyping and prototype results linked in the decision database to the iteration of which the evaluation or prototype is a part, to any risk analyses or assessments supported, and to any decisions supported or justified.

5.2.1.2 Required Attributes

When employed, prototyping shall:

a. Address all aspects of the emerging technology that bears upon its successful application, to include, for example, hardware, software, and manufacturing processes.

b. Be used to provide timely assessment of item testability to identify the need for new or modified test capabilities.

c. Conduct the same type of evaluations, and for the same purpose, when supporting product improvements and modifications to fielded (operational) systems.

5.2.2 Simulation

The Contractor shall employ simulation where cost-effective.

5.2.2.1 Required System Engineering Products

Evaluations of simulation and simulation results linked in the decision database to the iteration of which the evaluation or simulation is a part, to any risk analyses or assessments supported, and to any decisions supported or justified.

5.2.2.2 Required Attributes

The Contractor shall:

a. Evaluate the extent to which simulation can be applied to refine requirements and designs.

b. Evaluate solutions for people, products, and processes by simulating their interaction with their environment.

c. Evaluate simulation as an adjunct to prototyping.

5.3 System/Cost Effectiveness

5.3.1 Manufacturing Analysis and Assessment

Manufacturing analyses and assessments shall be conducted to support the development of people, product, and process requirements and solutions necessary to produce system end items.

5.3.1.1 Required System Engineering Products

Tradeoffs and other analyses 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.

5.3.1.2 Required Attributes

The Contractor shall:

a. Perform manufacturing analyses that include producibility analyses and manufacturing and production inputs to system effectiveness, trade-off studies, and life-cycle cost analyses.

b. Evaluate alternative designs and capabilities of manufacturing.

c. Identify, assess, and document long lead time items, material source limitations, availability of materials and manufacturing resources, and production cost.

d. Identify manufacturing-critical characteristics of people, product, and process solutions and their risks included in risk management efforts.

5.3.2 Verification Analysis and Assessment

The Contractor shall conduct verification analyses and assessments to support the development of people, product, and process solutions necessary to verify that system end-items satisfy their requirements.

5.3.2.1 Required System Engineering Products

Tradeoffs and other analyses 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.

5.3.2.2 Required Attributes

Verification analyses shall:

a. Address verification requirements and criteria for solution alternatives; definition of verifications to demonstrate proof of concept; and development, qualification, acceptance,

pertinent operational, and other testing. Life cycle requirements for test consistency in and across the solution set shall be determined.

b. Address the requirements and procedures needed to verify critical verification methods and processes (such as key methods, assumptions, and data used in verifications by analysis). Verification-critical characteristics of people, product, and process solutions shall be identified and their risks included in risk management efforts.

5.3.3 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.

5.3.3.1 Required System Engineering Products

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

5.3.3.2 Required Attributes

a. Deployment analyses and assessments shall 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 (see 5.5.8);

(5) Early deployment of training items and personnel;

(6) Initial provisioning and spares;

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

(8) Site transition requirements.

b. Deployment-critical characteristics of people, product, and process solutions shall be identified and their risks included in risk management efforts.

5.3.4 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.

5.3.4.1 Required System Engineering Products

Tradeoffs and other analyses 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.

5.3.4.2 Required Attributes

The Contractor shall:

a. Analyze and assess the operational use of alternative solutions addressing interactively:

   (1) The way the 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) Required joint and combined operations; and

   (4) Identified modes of operational deployment and employment.

b. Identify and include Operations-critical characteristics of people, product, and process solutions and their risks included in risk management efforts.

5.3.5 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.

5.3.5.1 Required System Engineering Products

Tradeoffs and other analyses 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.

5.3.5.2 Required Attributes

Supportability analyses shall**:**

a. Be used to assist in the identification of data and procedures needed in specifications and other development documentation to provide system life cycle support (e.g., additional interface information and verification requirements for utilization of "used" parts). Supportability analyses shall address:

   (1) All contractually specified levels of operation, maintenance, and training for system end-items;

   (2) The planned life cycle to ensure that system end-items satisfy their intended use; identification of supportability-related design factors;

   (3) The development of an integrated support structure (people, products, and processes); and

   (4) Support resource needs, including parts, people, facilities, and materials.

b. Identify and include supportability-critical characteristics of people, product, and process solutions and their risks included in risk management efforts.

5.3.6 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.

5.3.6.1 Required System Engineering Products

Tradeoffs and other analyses 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.

5.3.6.2 Required Attributes

Training analysis shall**:**

a. Include 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. Address initial and follow-on training necessary to execute required tasks associated with system end-item use.

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

5.3.7 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.

5.3.7.1 Required System Engineering Products

Tradeoffs and other analyses 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.

5.3.7.2 Required Attributes

These analyses shall:

a. Include environmental factors for process wastes and outputs as well as used products and components.

b. Evaluate alternative disposal methods for system parts and materials and requirements for new or modified methods determined. Methods addressed should include storage, dismantling, demilitarization, reusing, recycling, and destruction.

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

d. Identify disposal-critical characteristics of people, product, and process solutions and their risks included in risk management efforts.

5.3.8 Environmental Analysis and Impact Assessment

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

5.3.8.1 Required System Engineering Products

a. Tradeoffs and other analyses 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.

b. Any reports documenting the results that are otherwise required by the contract and that shall be consistent with the decision database at the time of submission.

5.3.8.2 Required Attributes

The Contractor shall:

a. Adhere to all applicable statutes and to contractually designated hazardous material lists.

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

c. Define and assess methods to mitigate problems and impacts identified from this analysis.

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

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

f. Avoid use of materials that present a known hazard to the environment to the extent practical.

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

5.3.8.3 Required System Engineering Products

Report documenting results.

5.4 Implementation Tasks

Implementation tasks shall be conducted interactively with the systems engineering process as needed to satisfy contract requirements.

5.4.1 Required Attributes

The Contractor shall:

Conduct developmental test and evaluation to validate technologies for application to system solutions, acquire definition information to support synthesis, and acquire verification information to support assessments in systems analysis and control.

Required System Engineering Products:

Document the results in the decision database linked to the iteration in which they were developed and any decisions they support or justify.

5.4.2 Verification

People, product, and process solutions shall be verified by design analysis, design simulation, inspection, demonstration, or test.

5.4.2.1 Required Products

Verification Results.

5.4.2.2 Required Attributes

a. The Contractor shall verify:

   (1) Required performance of all critical characteristics shall be verified by demonstration and test. Where total verification by demonstration or test is not feasible, testing shall be used to verify key characteristics and assumptions used in the design analysis or simulation.

   (2) Design analysis and simulation shall be used to complement, not replace, demonstration and test.

b. Tests shall include system effectiveness evaluations and manufacturing process proofing. Commensurate with the contractual effort, the Contractor shall:

   (1) Conduct verification of the physical architecture (including interfaces) from the lowest level up to the total system to ensure that functional and performance requirements are satisfied;

   (2) Generate evidence necessary to confirm that configuration items meet their requirements;

   (3) Validate technologies for use in people, product, and process solutions, considering cost, schedule, performance, and risk using established criteria; and

   (4) Verify that materials employed in system solutions can be disposed of in a safe, environmentally compliant manner.

5.4.2.3 Required System Engineering Products

Report documenting results.

5.5 Technical Reviews

The Contractor shall conduct technical reviews in accordance MIL-STD-1521C and with the IMP/SEMP, or as required elsewhere in the contract. Typically, reviews are co-chaired by the Government and Contractor, and participants are those who have a stake in the objectives of the review.

5.6 Systems Engineering Capability Assessment

The Government may assess the Contractor's capability to satisfy contractual requirements for systems engineering. Upon request of the Government, the Contractor should make available for Government review additional systems engineering procedures and data.

5.6.1 Required Attributes

The review consists of a combined demonstration and analysis of features in the Contractor's procedures, data, facilities, personnel, and tools that are key to the satisfaction of contract requirements.

a. Prior to contract award, this review is used by the Government to assist in identifying the risk in achieving required accomplishments.

b. During the contracted period, the review may be conducted to evaluate the cause of not meeting contractual requirements and to evaluate the viability of "get well" actions, if developed.

5.6.2 Required System Engineering Products

System engineering procedures.

6. Notes

6.1 Intended Use

This section contains information that may be helpful, but it is not mandatory.

The primary purpose of this document is to be used as a compliance document to be applied by the Government on the Contractor's contracts. Therefore, the requirements herein are primarily intended to be Contractor requirements. It can, however, 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 SOW, tailoring this document to include tasks from other standards selected for contractual application, executing the complete, integrated task set via the SEMP, or 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 applied by the Government as follows:

a. As points of departure for defining the Government's requirements for systems engineering in an RFP or Contract. Toward this end, the requirements in this section can be applied by tailoring the requirements in Subsection 4.2 and definitions in Section 3.0 consistent with the objectives and constraints of the program and contract, or by developing tailoring for additional government, industry, or professional society systems engineering standards to bring them into compliance with Sections 4.2 and 3.0 below. 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, "Evaluation Criteria and/or Source Selection Standards for evaluating either:

   (1) Proposed alternative standards or corporate policies, or

   (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. To be used, subsequent to tailoring, by the Government as a "check list" for monitoring the Contractor's systems engineering processes and products.

This standard applies to all acquisition Phases of DODI 5000.2 and NSS 03-01, pre-Phase A, Phase A, Phase B, and Phase C (See Figure 2). The requirements herein respond to and provide important steps in implementing DoD direction including the following from the DoD acquisition policy:

> *Acquisition programs shall be managed through the application of a systems engineering approach that optimizes total system performance and minimizes total ownership costs.*[7]

> *Effective sustainment of weapon systems begins with the design and development of reliable and maintainable systems through the continuous application of a robust systems engineering methodology.*[8]

Many other directives and instructions in DoDD 5000.1 and DoDI 5000.2, 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 conducted under the National Security Space Acquisition Policy and DoDI 5000.2. NSSAP 03-01 states the following:

> *Assess the system engineering process used for requirements traceability and verification. Provide a requirements flow down. At KDP-C, provide a requirements verification matrix to show design to requirement traceability and the test method to verify*.

6.2 Data Requirements

In the development of National Security Space systems, it is the responsibility of the Government to ensure that adequate systems engineering (SE) 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 are required and when they are needed. Aerospace Report No. TOR-2004(8583)-3227 lists below a baseline set of 18 SE CDRL items that may be tailored to meet specific National Security Space program requirements in accordance with the acquisition phase and scope of the effort. 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.

7. DoDD 5000.1, **The Defense Acquisition System**, May 12, 2003, Section E1.27
8. DoDI 5000.2, **Operation of the Defense Acquisition System**, May 12, 2003, Section 3.9.2.2

SE CDRL Item Reference

1.	Systems Engineering Management Plan Mil-Std 499B	DI-MGMT-81024
2.	Risk Management Plan	ISO 17666:2003
3.	Configuration Management Plan	DI-CMAN-80858A or B
4.	Verification Plan Aerospace	TOR-2004(3901)-3242 2
5.	System/Segment Interface Control Specification	DI-CMAN-81314
6.	Logistics Management Information	DI-ALSS-81529 DI-ALSS-81530
7.	System/Subsystem Specification	DI-IPSC-81431A
8.	Contract Work Breakdown Structure	DI-MGMT-81334A
9.	Earned Value Reports	DI-MGMT-81466
10.	Integrated Master Schedule	DI-81183A
11.	Design Review Package (SRR, SDR, PDR, CDR)	DI-ILSS-81335
12.	Integration and Test Plan (SEMP)	DI-MGMT-81024
13.	Engineering Change Proposal	DI-CMAN-80639A/B
14.	Failure Summary and Analysis	DI-RELI-80255
15.	Tailored Specification or Standard Aerospace TOR	2003(8583)-2 Rev.24
16.	Data Accession List	DI-MGMT-81453
17.	System Safety Program Plan	DI-SAFT-81626T
18.	Software Development Plan	DI-IPSC-81427A

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.

6.3 Tailoring Guidance

This standard is applied at the discretion of the Government. In each application, this standard should be tailored to the specific requirements of a particular program, program phase, or contractual structure as directed by the Government. Tasks which add unnecessary costs, data, and any factors which 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 draft Request for Proposal. MIL-HDBK-248 provides additional tailoring guidance.

6.3.1 Tailoring Considerations

The systems engineering process discussed in Subsection 4.1 of this standard is applicable to all system development, irrespective of complexity, risk, or scope. However, the system functions to which these processes will be applied (per Figure 1 in Subsection 1.3) as well as the number and sequencing of technical reviews, the use of iteration and recursion, and the specific systems engineering and other artifacts produced will vary depending on many factors. In addition, the relative intensity of the various systems engineering activities within the system engineering process will also vary from one

system acquisition to the next. The Contractor shall apply tailoring per this guidance subject to the Government's direction and approval. The Contractor shall use this tailoring guidance to inform its choice of tools, measurements, and metrics programs, and specific methods and tasks.

The objectives of the contract effort and the inputs to the systems engineering process scope the breadth and depth of application. To assist in defining the depth of application and level of effort, the following inputs should be identified for any application of this document.

6.3.1.1 The Applicable Acquisition Guidance

Systems will be acquired under acquisition guidance such as the DOD 5000 series, the NSSA 03-01, NRO Directive 7, or other guidance. These are somewhat different approaches to acquisition, and have different emphases with regard to upfront versus follow on effort and the degree of system definition required by the various acquisition milestones.

6.3.1.2 Use of Evolutionary Acquisition[9]

Evolutionary acquisition is described in DOD 5000 as 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.

6.3.1.3 New Development vs. COTS Systems[10]

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.

6.3.1.4 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.

6.3.1.5 System Size and Complexity

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

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9 Pennett, Gary, "Defense and Intelligence Systems Acquisition Overview: Part I – Defense Community", The Aerospace Institute, Draft Briefing Slides as of 01 March 2005.

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

6.3.1.6 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 than systems requiring the same.

6.3.1.7 Magnitude of Technical Risk

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

6.3.1.8 Policies, Regulations, Standards and Laws

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

6.4 Robustness and Flexibility

Many systems produced by the DoD and 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 of 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.[11] These concepts are represented in Figure 6.1. The B-58, in the first quadrant, was optimized for a single mission, that of delivering nuclear weapons at supersonic speeds and at high altitude. As 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 6.1, 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 the functional requirements for which 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.

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11 Workshop on Systems Engineering for Robustness, 8–9 June 2004, Lean Aerospace Institute, Massachusetts Institute of Technology, and Assistant Secretary of the US Air Force for Acquisition

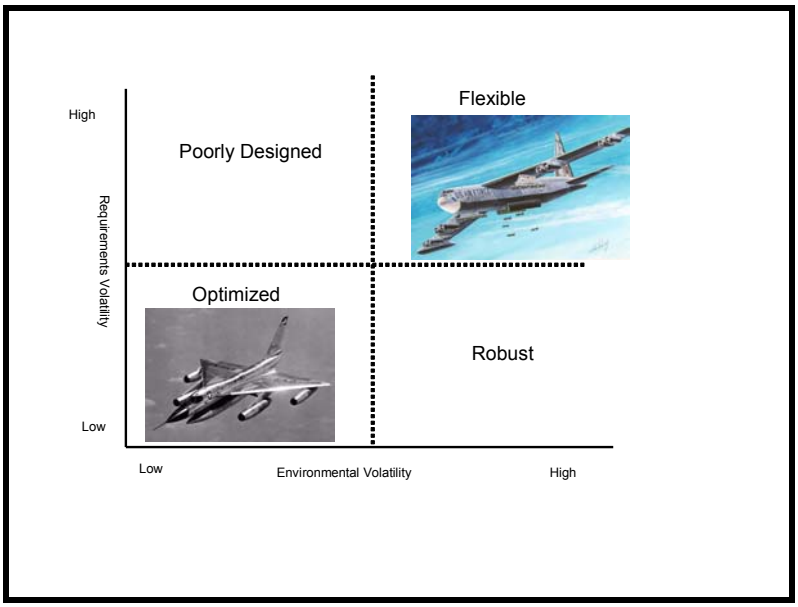

Figure 6.1. Flexible, robust, and optimized systems.

6.5 Evolutionary Acquisition

With the new DOD 5000 series, the DoD has come to emphasize evolutionary acquisition (EA). EA is described in the Defense Acquisition Desk (DAD) Book 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, and the maturation of technologies that lead to disciplined development and production of systems that provide increasing capability towards a materiel concept.[12]

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 war gaming. 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:

12 Defense Acquisition Desk Book (DAD), Sec 3.3.1,
http://akss.dau.mil/dag/DoD5000.asp?view=document&rf=DoD5002\Procedures_3.3.asp

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

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

- The integrated logistics support plan (ILSP) must account 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.

The system must be designed for growth. There must be slack bandwidth, electrical power, HVAC, etc. so that future functional requirements can be accommodated.

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Appendix A—Glossary

Refer to a modern dictionary of the American language for the definition of any terms not provided below. For conciseness, the definitions below often cite terms defined elsewhere in the table. Still other definitions are provided to relate commonly used terms to those used in this standard. Notes in *italics* are only for information.

acceptance	For hardware, the verification that a component or higher level of integration, together with its embedded software, meets all requirements and constraints for which the verification method is test, inspection, or demonstration following any procedures to ensure workmanship such as environmental stress screens.
accomplishment	See significant accomplishment.
accomplishment criteria	See significant accomplishment criteria.
allocated baseline	The allocated baseline includes (a) the physical hierarchy, (b) 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 (c) separable documentation identifying all design-to requirements and constraints for each component or computer software unit and each separately integrated grouping of components and/or computer software units.
allocation	1. All or a subset of a requirement 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. 3. The results of (2).
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	1. The performance and assessment of calculations (including modeling and simulation) to evaluate requirements or design

	approaches or compare alternatives. 2. The verification method of determining performance (a) by examination of the baselines for a system or system product, (b) by performing calculations based on the design release baseline and assessing the results against the requirements of the allocated or requirements baseline, (c) by extrapolating or interpolating empirical data collected using system products built, bought, or coded according to the baselines and assessing the results against the baseline requirements, or (d) by a combination of all of the above.
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.
Analysis of Materiel Approaches (AMA)	The AMA will determine the best materiel approach or combination of approaches to provide the desired capability or capabilities. The AMA will determine the best way(s) to use materiel approach(es) to provide a joint capability. Generally, it will not consider which specific "systems" or "system components" are the best. For example, the AMA may compare the capability provided by a space platform with that by provided by an unmanned aerial vehicle (UAV) but will not usually assess the best alternatives within the preferred materiel approach (space or UAV in this example). The latter analysis will usually occur in an analysis of alternatives (AoA) after the ICD is approved.
architecture	A term that has many definitions across the various technical communities. For its usage in this standard, see **integrated architecture**, **functional architecture**, and **physical architecture**.
assigned baseline	See Allocated Baseline.
assignment	See Allocation.
attribute	1. A quality, property, or characteristic of a systems engineering product. 2. A testable or measurable characteristic that describes an aspect 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.
balanced	A set of system requirements, requirements allocations, functional architecture, and/or design for which the system effectiveness, life cycle 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 to include avoiding the potential for significant added cost, schedule, or risk for small gains in capability.
baseline	*noun:* Document(s) or decision data base(s) that record the current set of requirements for the system and its design or system product solutions. *Note: This standard defines and applies four baselines: the requirements baseline, the allocated or assigned baseline, the design or design release baseline, and the product or product configuration baseline. Completing and maintaining these four baselines at minimum cost and schedule and acceptable risk is the objective of the systems engineering requirements in Section* 4.2. *verb:* To formally approve a baseline.
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 and education, personnel and facilities (DOTMLPF). In the case of proposed materiel solution, the definition will progressively evolve to DOTMLPF performance attributes identified in the ICD, CDD, and CPD. See CJCSI 3170.01C and CJCSM 3170.01.
capability gaps	Those synergistic resources (DOTMLPF) that are unavailable but potentially attainable to the operational user for effective task execution.
Capstone Requirements Document (CRD)	A document that contains capabilities-based requirements, usually for a Family or System of Systems (FoS or SoS) that facilitates the development of CDDs and CPDs for an individual system by providing a common framework (such as for interoperability) and operational concept to guide their development.
change	A modification of an approved requirement, baseline, or product as documented in the decision data base, specification, and any other configuration management documentation and approved in accordance with the contract.
change control	The engineering management function of (a) limiting change to a baseline or other product to that which has been (i) assessed for impacts to capabilities, cost, schedule, risk, and growth potential and (ii) approved by documented procedures in accordance with

	the contract and (b) assuring implementation of all changes so assessed and approved to the products of the program.
Combat Capability Production Document (CCPD or C-CPD)	Used to document urgent, time-sensitive requirements to resolve deficiencies that arise during combat or crisis operations where there is a threat of loss of life or imminent loss of life is apparent. A C-CPD is usually documented and staffed by an expedited process.
Command, Control, Communications, Computers & Intelligence Support Plan (C4ISP)	A plan usually developed by the SMC planner or SPO during system development. The C4ISP development and review process provides a mechanism to identify and resolve implementation issues related to C4I support and information technology system (including National Security Systems [NSS]) interface requirements. The C4ISP identifies needs, dependencies, and interfaces focusing attention on interoperability, supportability, and sufficiency concerns. See the Interim Defense Acquisition Guidebook, Appendix 5 (AP5) for staffing procedures and format.
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 other hardware or software products, that is viewed as a **separate entity** for **purposes of design** or some other reason**,** and for which **the design is separately qualified**. Hardware components may be further divided into additional components, other lower tier products *(sometimes given names such as subassemblies)*, parts, materials, processes, and data; software components may be further divided into additional components and/or software units.
computer software	Refers, as they evolve, to the design-to requirements in the allocated baseline, code-to requirements in the design release, and the resulting software code and documentation for the complete set of computer software components and computer software units in the system.
computer software unit	A subdivision of a computer software component.
concept	See system concept.
concept of operations (CONOPS)	1. An Air Force CONOPS is 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. Air Force CONOPS are evaluated by a Capability Review and Risk Assessment (CRRA) and then serve as the basis for subsequent CRRAs which are conducted to evalu-

	ate the Air Force's ability to employ capabilities and accomplish its mission when called upon as described by Air Force CONOPS. See the draft AFI 10-601, 24 July 2003, or its successor. 2. A concept, usually developed by the operator/user with support from the SMC planner or SPO, for employing and supporting a capability or system concept. The CONOPS is used in System Technical Requirements Analysis to identify system functional requirements and design constraints.
configuration item	See component.
constraint	See design constraint.
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. See DoDI 5000.2, 12 May 2003, Sections E6.1 and E6.2 or the NSSAP 03-01, October 6, 2003, Appendix 3, AP3.6.3.2d, and DoD 5000.4-M, especially Chapter 1.
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 "trade space" between the objective and the threshold. Trade-offs outside the trade space created by objectives and thresholds (and other program constraints) must be approved by both the MDA and the capability document approval authority. See the Interim Defense Acquisition Guidebook, October 30, 2002, Section C.1.3.
cost constraints, cost goals, or cost requirements	The financial objectives or thresholds for the program or contract and their allocation either to the system products and/or to program or contractual phases. Often expressed in terms of development, design-to-cost (DTC), unit production cost (UPC), production and deployment, operations and support (O&S), and/or life cycle cost (LCC) goals, targets, or thresholds for the program or a system product. Cost goals and requirements reflect that fiscal constraints are a reality in defense acquisition.
decision data base	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.
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 inherent to the product and all data required for verification is obtained by observing operation of the product.
deployment function	Tasks to be 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 and which are inferred from the nature of the proposed solution; the applicable verification, rework, storage, transportation, operating, and support environments; policy; law; best engineering practice; or some combination of the above.
design	*noun*: The build-to, buy-to, code-to, or author-to; integrate–to; verify-to; deploy-to; train-to; support-to; operate-to; and dispose-to requirements (instructions and plans) for each system product in the physical hierarchy and such lower tier products as may be required to satisfy the requirements and allocated baselines as they evolve and as captured in a preliminary, draft, or approved design release baseline. The design, in effect, extends the allocated baseline down to define the requirements for all parts, materials, processes, code, and data necessary to build, buy, or author; integrate; complete both qualification and acceptance verification on all system products (including lower tier products not identified as part of the allocated baseline); train Government and developer personnel; and deploy, operate, support (sustain), and dispose of the system and each integrated grouping of products over the system life cycle; and the Government personnel skill and manpower levels over the system life cycle. *verb:* Architecting, engineering, or selecting system products (including processes) and corresponding personnel manpower, skill levels, and specialized training that satisfy all requirements and describing them so that the products can be manufactured, coded, or bought; verified; integrated; deployed; operated; supported; and disposed of and so that the personnel can be selected and trained. In the case of new or modified Government facilities, the integrating, system, or associate Contractors' direct responsibilities for the end result usually end with the establishment of design 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 constraints may include interface and interoperability; natural, induced, or threat environments; physical mass and dimensional; reliability; availability; maintainability; human factors; logistics support; personnel resource (skill levels and manpower) and training; standardization (perhaps to realize any of the other factors in this list); design and construction practices; public law or regulation; fiscal considerations or program budget (also called a cost constraint); or other factors.
design release baseline	The initially documented, validated, and approved (a) design for each system product*, including integrated assemblies of products,* and (b) 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-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. In the case of some components or software, "design" may amount to selection of COTS or NDI hardware or the decision to reuse software, but the design-to requirements are still necessary systems engineering products for use in verifying that each selected product meets the requirements and constraints based either on previously collected verification data, or, if necessary, additional verification steps. At the lower levels of the physical hierarchy, the design-to requirements apply to hardware and software components, computer software units, new or modified Government facilities, or Government furnished products such as equipment (GFE). At higher levels, the design-to requirements apply to integrated assemblies of components, computer software units, or GFE or to such products or assemblies of such products installed in Government facilities.
development function	Tasks to be 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.
Developmental Test & 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.
disposal function	Tasks to be 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, de-militarization policy, and environmental laws and regulations. The function addresses the short and long term impact to the environment and health hazards to humans and animals as well as recycling, material recovery, salvage for re-utilization, demilitarization, and disposal of by-products of all other functions, i.e., across the life cycle.
document, documentation, documented	Information that is stored on any media and that can be retrieved and applied or reviewed over the life cycle of a system
earned value management system	See the **Interim Defense Acquisition Guidebook**, October 30, 2002, Section AP4.
effectiveness	See "system effectiveness."
element	In a system, baseline, or functional architecture**,** any system product, any representation of a system product, any requirement or allocation of a requirement, or any logical or abstract representation or decomposition thereof (such as a function, sub-function, object, or data structure). *Note: An element is any system product, any systems engineering product, or any subset thereof.*
end product	A system product to be delivered to the customer.
environment, environmental	The natural and induced conditions experienced by a system including its personnel and products (including processes) during manufacturing, verification, rework following a verification procedure, transportation, storage, operational use, stand-by, and maintenance. The natural conditions include space (exo-atmospheric), atmospheric (weather, climate), ocean, terrain, and vegetation. Induced conditions include manufacturing (process conditions, clean room, storage), test, transportation, storage, normal operations (thermal, shock, vibration, electromagnetic, the range of power inputs), maintenance, combat (dust, smoke, blast, electromagnetic, laser, nuclear, chemical, biological), and the threat (existing and potential threat systems that could be used to counter or exploit the system to include electronic warfare and communications interception). *The environment defines design constraints which are part of the requirements and allocated baselines.*
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.
event	A point in a program or contract defined by significant accomplishments and accomplishment criteria (or metrics) in the IMP. The goal for the calendar date to complete an event is documented

	in the IMS.
external interface	A design constraint imposed on a system by 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.
feasible	Capable of being developed; manufactured, procured, coded, or authored; integrated; deployed, operated; and supported to meet the requirements for and constraints on the system or product and objectives of the program.
formal	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 sub-functions to the point that each sub-function or set of sub-functions 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 sub-function 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 sub functions, the associated time-lines, and the allocation of the performance requirements and constraints in the requirements baseline to the functions and sub-functions. A systems engineering product. *Note: A specific form of a logical solution representation as used in ANSI/EIA-632-1998.*
functional flow, functional flow block diagram	A diagram showing the relationship (sequential, parallel, or contingent) between functions (represented by blocks). It can also show the facility or node at which the function is performed and any other elements that further describe each functional path and the conditions for each path.
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 docu-

	mentation (and not including computer software).
IMP, IMS	See Integrated Master Plan, Integrated Master Schedule.
increment	A militarily 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.
information database	See Decision data base.
information exchange requirements (IER)	Requirements that define the interoperability KPP threshold and objective values documented in CDDs, CPDs, and CRDs. The IERs should reflect both the information needs required by the system under consideration and the needs of other supported systems. The IERs should cover all communication and computing requirements for command, control, and intelligence of the proposed system.
Initial Operational Test and Evaluation (IOT&E)	See "Operational Test and Evaluation (OT&E)."
inspection	The verification method of determining performance by examining (a) engineering documentation produced during development or modification or (b) 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 an 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. The integrated architecture is depicted by multiple views or perspectives (operational view, systems view and technical standards view) that first identify the needs for integration and interoperability across the nodes operated by the military forces, then across the Family or System of Systems (FoS or SoS) that provide the interoperability, and finally in terms of the technical standards that each system is to design to. See operational view, system view, and technical standards view.
integrated database	See decision database.
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. The critical processes are described by narratives that include Objectives, Governing Documentation, and an Approach. 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 to include 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). The 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 computer software units, hardware or software components, or higher tier products to build and subsequently verify still higher tier products including the system. Part of the design release or product configuration baseline.
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 constraint	See interface requirement.
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 requirement	The functional and physical design constraints imposed on each other by two or more functions, system products, or systems or between a system and a facility. *Notes: Functional interfaces include signal, electrical, electromagnetic, and software. Physical interfaces include keep-out volumes, mating surfaces, and con-*

	nectors.
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.
internal interface	The functional and physical design constraints imposed on a system product resulting from the designs selected for other system products in the same system. Also, see interface requirement and external interface.
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.
item	See component.
key performance parameter (KPP)	An attributes or characteristics considered most essential for an effective military capability.
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 & evaluation; procurement (to include production testing, deployment, and support to IOT&E); operations & support (to include training, IOT&E, and FOT&E); Government facilities; and disposal. For defense systems, Life Cycle Cost is also called Total Ownership Cost (TOC).
manufacturing function	Tasks to be performed to convert materials and parts into a system product ready for verification, training, and/or deployment.
material	A natural element, alloy, mixture, or compound used in a manufacturing operation and which becomes either a permanent portion of a manufactured system product or which can leave a remnant, residue, coating, or other material that becomes or affects a permanent portion of a manufactured system product. All required properties and processing steps are specified as part of the design and controlled as part of the design release or product configuration baseline.
materiel approach or materiel	A defense acquisition program (nondevelopmental, modification

solution	of existing systems, or new program) that satisfies, or is a primary basis for satisfying identified warfighter capabilities. In the case of Family or System of Systems (FoS and SoS) approaches, an individual materiel solution may not fully satisfy a necessary capability gap on its own.
near-NDI or N-NDI	See Non-Developmental Item (NDI).
non-developmental item (NDI)	Any system product that is (a) available in the commercial marketplace or (b) 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 (a) have been developed but are not yet available in the commercial marketplace or in use by a government entity or (b) require only minor modification or upgrade are termed Near-NDI or 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. An objective value may be the same as the threshold when an operationally significant increment above the threshold is not significant or useful. Source: CJCS 3170.01C and CJCSM 3170.01.
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 & Evaluation (OT&E)	Independent test 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.
operational view, operational architecture view (OV)	A description of the tasks and activities, operational elements, and information exchanges required to accomplish DoD missions. DoD missions include both warfighting missions and business processes. The OV contains graphical and textual systems engineering products that comprise an identification of the operational nodes and elements, assigned tasks and activities, and information flows required between nodes. It defines the types of information exchanged, the frequency of exchange, which tasks and activities are supported by the information exchanges, and the nature of information exchanges in detail sufficient to ascertain specific interoperability requirements. Several products have been defined making up the OV – see Section 4 of the **DoD Architecture Framework, Volume II**, 15 Jan. 2003.
operations function	Tasks to be performed subsequent to verification and deployment to accomplish defined missions in either the expected peacetime or wartime environments excluding training, support, and disposal.
operator	An operational command or agency that employs acquired systems for the benefit of users. Operators may also be users.
part	A system hardware product which cannot normally be disassembled without destruction or impairment of the intended use. The requirements for parts are normally defined in design and controlled as part of the design release or product configuration baseline. A part may be treated differently from a component in that, to the extent required or permitted by the contract requirements, it may be subject to different selection, documentation, approval, and configuration management requirements consistent with the developer's corporate policies. *Examples: integrated circuit, relay, roller bearing, and fastener.*
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 architecture	1. Any abstract representation of the physical system, system concept, or system design. 2. The physical hierarchy. 3. The physical hierarchy and the allocated and derived requirements and design constraints for each element in the hierarchy. 4. All system products (including processes) and personnel that make up the system and their organization or relationships.

	Notes: *1. The requirements in this Standard do not use the term – it is referenced in a few places to identify alternatives to the terms that are used.* *2. The physical architecture can be viewed as any physical representation, as synonymous with the physical hierarchy, as an intermediate step between the development of the functional architecture and the physical hierarchy, on the one hand, and the approval of the allocated baseline, on the other hand – in other words, a preliminary allocated baseline, or the extension of the physical hierarchy to include all products and personnel in the system design.*
physical hierarchy	The hierarchical arrangement of system products 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 products 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 components and computer software units necessary to satisfy the requirements baseline over the life cycle **whether deliverable or not**. It includes all hardware and software to be delivered to the customer including developer-supplied support equipment, factory support and test equipment and tooling (except that used for products *such as COTS* already in production and applied without modification), and new or modified Government facilities, property, or equipment to include Government-inventory support equipment which collectively make up the system that satisfies the requirements baseline. It includes new or modified developer facilities if and only if their construction and operation are funded or partially funded by the same contract as the remainder of the system. Also sometimes called the product tree or the physical architecture.
process	Any 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	See system product and systems engineering product.
product configuration baseline, product baseline	The initially documented and approved update to the design release baseline for one or more system products after confirmation (a) of qualification that the product design satisfies all performance and functional requirements and constraints in the cur-

	rent allocated and design release baselines, (b) that the as-built, as-coded, or as-integrated product is accurately reflected in the baselines, and (c), 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 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.
product tree	See physical hierarchy.
qualification	1. For hardware, the verification that a component or higher level of integration, together with its embedded software, meets all requirements and constraints during the worst-case environmental **and** operating conditions anticipated over its life cycle. 2. For computer software, the verification that a component or computer software unit meets all requirements and constraints over the possible range of all variables, computational paths, and decision logic outcomes.
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. Often abbreviated Req. Ref.
requirements acceptability criteria	Complete: Requirements define a system that satisfies all user capabilities and requirements. All user requirements trace to system and lower level requirements. Concise: Ideally, only one plausible semantic interpretation is possible. The statement is written in unambiguous contract language. All terms are adequately defined. Correct: No errors exist that may effect the design. The parameters and their units are correct and consistent across all specs, ICDs, and Program Foundation documents. The related functionality is accurately captured in each requirement statement. All allocations are correct, consistent, & clear. Consistent: Requirements do not conflict with each other. Efficient: Minimum set of requirements have been identified. No

	overlap or redundancy between requirements. Evolvable: Requirements and associated functionality can evolve when incremental capabilities relating to those requirements are intended. Traceable: An audit trail exists from the origin of the requirement and how it evolved. The sources are valid and current. Requirements trace to supporting rationale for requirements derivations, supporting analyses/trades, Issues, actions, and decisions to conclude each requirement. Requirements trace to verification requirements and planning. Verifiable: The requirement is verifiable by Test, Demo, Analysis, and/or Inspection. Validated: The requirement can be validated to a stated user need and consistent with Program Foundation capabilities and operational 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 initially 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 next level (and lower levels if necessary to capture the systems engineering foundation for the program), and all changes thereto approved in accordance with the contract.
risk	A measure of the uncertainty of attaining a requirement, goal, or objective pertaining to technical performance, schedule, or cost and the consequences of not attaining it. The uncertainty is the result of one or more undesirable events that could occur during the system life cycle for which insufficient resources and time are programmed to overcome them. The consequences are measured in terms of the inability to provide the needed operational capability or of exceeding program cost or schedule constraints (such as the programmed budget and directed schedule).
schedule, schedule	Progress characteristics imposed on the completion of program

requirements	phases, on contract events and deliveries, and operation and support parameters such as time between failures and repair time.
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.
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.
specification	A description of the essential 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	Tasks to be performed to provide support for operations and training. The tasks include the acquisition and supply of spares, depot level maintenance, and the acquisition and maintenance of the facilities and selection and training of personnel to carry out the support function.
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 which interact with one another in an organized or interrelated fashion toward a common purpose which 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. The system products include factory, operational and depot hardware and software (delivered and developer); purchase requirements; manufacturing processes and instructions; verification plans and procedures; deployment plans and procedures; training plans and courses; technical manuals; support plans and spare part requirements; and disposal plans, instructions, and if needed, equipment. An acquisition program develops, produces, and deploys the products and defines the skill and manpower levels for the personnel.

system architecture view	See system view.
system concept	A rudimentary or unfinished design, used for preliminary assessments of system effectiveness, cost, schedule, or risk which provide the basis for more detailed designs through further iteration of the requirements, functional, and design analyses as required by this standard.
System Design Review (SDR)	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 data base 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 SDR 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 SDR data is the Decision Data Base documenting or demonstrating that these seven systems engineering requirements have been satisfied.
system effectiveness	Quantified or otherwise objective 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 product	Any separately identifiable portion of a system other than personnel, whether delivered or not, to include hardware, software, firmware, process, Government facility or modification of an existing Government facility, modification to existing equipment or property, document, manual, drawing, instructions, data, or combination thereof. Services are not system products but data that define the required scope of services such as Contractor support during IOT&E or operations are system products.
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)	A DIA validated intelligence document 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 non-lethal 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 (a) 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, (b) deficiencies discovered during verification (DT&E) (and validation – IOT&E – to the extent completed) have been resolved and changes approved and implemented, (c) all other approved changes have been incorporated into the affected baselines and the affected system products verified to comply, (d) the life cycle cost projections remain consistent with the program affordability constraints, (e) the requisite plans, procedures, resources, and facilities are available (or on schedule) to initiate production, production verification, training, deployment, operations, support, and disposal, (f) the remaining risks have been identified and can be handled in the context of the planned program, and (g) the decision data base has been maintained to capture all changes and updates so that it completely and accurately captures (i) the current approved baselines and (ii) the verification data showing compliance with the baselines. The primary data for the SVR is the decision data base documenting or demonstrating that these seven systems engineering requirements have been satisfied.
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. 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. 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 Jan. 2003.
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.
systems engineering	1. As a process, service, function, or activity, an interdisciplinary effort to iteratively and recursively (a) 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,[13] (b) 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 that collectively provide a design response to the capability needs that is balanced with respect to system effectiveness, cost, schedule, risk and evolutionary growth potential, (c) maintain those baselines over the life cycle of the system, (d) assess compliance with the baselines as development evolves, and (e) verify that the baselines have been met by products built, coded, bought, and integrated IAW the design and then support the validation (through OT&E) that the needed capabilities have been provided. 2. As a team or organizational entity, a group that is directly responsible for certain systems engineering products and for facilitating or monitoring others as a staff function to a program or system product manager. *Note: All of the technical organizations involved in a program or contract have a role in the systems engineering process so it encompasses much more than what the systems engineering team or office does.*
systems engineering product	A tangible and documented result of systems engineering to include plans, tradeoff and other analyses, the baselines, the func-

13. See DoDI 5000.2, May 12, 2003, Sections 3.2 through 3.6.7.

	tional architecture, assessments, drawings, instructions, verification data, or validation results.
systems engineering requirement	Statement defining a mandatory contract compliance requirement.
tailoring	The evaluation of text, figures, graphs, or tables of specifications, standards, and other requirements or tasking documents to determine the extent to which they are applicable to a specific acquisition contract and their subsequent acceptance, alteration, deletion, or extension in order to balance the capabilities to be provided by the contract with the resulting cost, schedule, and risk.
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 technique for 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 around the anticipated indicate a need for evaluation and corrective action.
technical view, technical standards view, technical architecture view, technical architecture profile (TV)	The minimal set of rules governing the arrangement, operation, interaction, and interdependence of system products whose purpose is to ensure that a conformant system satisfies a specified set of requirements. The TV provides the technical systems-implementation standards or guidelines upon which engineering specifications are based, common building blocks are established, and system product lines are developed. The TV includes a collection of the technical standards, implementation conventions, standards options, rules, and criteria organized into profile(s) that govern system products and interfaces for a given integrated architecture. Several systems engineering products have been defined making up the TV – see Section 6 of the **DoD Architecture Framework, Volume II**, 15 Jan. 2003. See also definitions for the operational view (OV), system view (SV), and integrated architecture.
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. Any analysis of the data recorded in the test and that is needed to verify compliance *(such as the application of instrument calibration data)* does not require interpretation or interpolation/extrapolation of the test data.
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 complete a test.
test report	Documentation of compliance with the test plan and the compliance or non-compliance of the system products under test.
threat	1. Countries or groups that are considered to have a potential adverse impact on the national security of the United States. 2. Weapon systems that must be defeated by U.S. systems in battle and the environment created by those systems. *Note: Consult the latest version of DoDI 5000.2 and service acquisition policy. The threat information, to include the target data base, may be required to be validated by the Defense Intelligence Agency (DIA) or by a service intelligence agency. If so, such validation can require up to a year and should be scheduled accordingly.*
threat assessment	See "system threat assessment."
threshold	A minimum acceptable operational value below which the utility of the system becomes questionable. See CJCSI 3170.01C and CJCSM 3170.01.
time-line analysis	Analytical task conducted to determine the time sequencing and spacing between two or more elements of a functional architecture or of the operation of a design solution to define any resulting time, sequencing, or concurrency requirements or constraints. Examples:

	a. An analysis of the currency of data in a computational path. b. A profile detailing time delays through multiple functions involving communications or computation. c. The sequential interaction of a crew member with one or more subsystems.
Total Ownership Cost	A concept designed to determine the true cost of design, development, ownership and support of DoD weapons systems. At the DoD level, Total Ownership Cost is comprised of the 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 Life Cycle 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 data base) to any other element to which it has a master-subordinate (or parent-child) relationship.
trade space	The set or range of feasible alternatives to be compared to achieve a solution balanced with respect to system effectiveness, cost, schedule, risk, and potential for evolutionary growth.
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, designs. Often the basis for selecting less of one parameter in order to achieve a more balanced overall system result.
training function	Tasks to be 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.
unit	1. See component. 2. For computer software, a subdivision of a component. 3. A subdivision of time, fabrication or production quantity, or some other system or program parameter.
user	An operational command or agency that receives or will receive benefit from the acquired system. Combatant commanders and their Service component commands are the users. There may be

	more than one user for a system. Because the Service component commands are required to organize, equip, and train forces for the combatant commanders, they are seen as users for systems.
validation	1. For a baseline, the demonstration that it has its required attributes, that any assumptions necessary in its development are valid (i.e., acceptable to the customer), and that the effectiveness of the emerging system design can affordably satisfy the system technical requirements and constraints. 2. For a satellite or launch system, the certification that it is ready for launch. 3. For a system, the assessment of the operational test authority that the system is suitable for operations and continued production, if planned.
verifiable	System or system product compliance with the requirement can be verified at the level of system structure at which it is stated by a finite and objective and reproducible test, inspection, demonstration, or analysis.
verification	The task of determining whether a system or system product meets the requirements established for it.
verification function	Tasks to be performed to evaluate the compliance of the evolving system (system products and personnel) with the program or contract requirements. Includes analysis, demonstration, test, inspection, and special methods. The function includes technology assessments and demonstrations and all test and evaluation such as Development Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E). Also includes the evaluation of program or contract risks and monitoring the risks.
verification method	A way to verify that a solution meets a requirement. The usual verification methods are test, demonstration, inspection, and analysis. Other, special methods are also sometimes applied. The verification method for each requirement is included in the baseline containing the requirement.
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 B—List of Acronyms and Abbreviations

B1. Scope

This appendix provides a list of all acronyms and abbreviations used in this standard, with associated meaning. This appendix is not a mandatory part of this standard. The information contained herein is intended for guidance only.

B2. Applicable Documents

This section is not applicable to this appendix.

B3. Acronyms and Abbreviations.

Note: many terms used below are defined in Section Appendix A.

ADM	Acquisition Decision Memorandum
AFMC	Air Force Material Command
ANSI	American National Standards Institute
APB	Acquisition Program Baseline
ASR	Alternative Systems Review
B	Section of an RFP or model contract that specifies supplies or services and prices/costs
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
CCA	Critical Capability Area
CCPD or C-CPD	Combat Capability Production Document
CDD	Capability Development Document
CDR	Critical Design Review
CDRL	Contract Data Requirements List

CFE	Contractor Furnished Equipment
CFSR	Contract Funds Status Report
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
CPR	Cost Performance Report
CRD	Capstone Requirements Document
CSOW	Contract Statement of Work
CWBS	Contract Work Breakdown Structure
DAB	Defense Acquisition Board
DIA	Defense Intelligence Agency
DID	Data Item Description
DoD	Department of Defense
DOT&E	Director, Operational Test & Evaluation
DOTMLPF	doctrine, organization, training, materiel, leadership and education, personnel and facilities
DSAB	Defense Space Acquisition Board
DT&E	Development Test and Evaluation
DTC	Design to Cost (See also DTUPC, UPC)
DTUPC	Design to Unit Production Cost (See also DTC, UPC)
EA	evolutionary acquisition
ECP	Engineering Change Proposal
EDMs	engineering development models
EIA	Electronic Industries Alliance
EVMS	Earned value management system
F	Section or an RFP or model contract that specifies delivery schedules
FCA	Functional Configuration Audit
FFBD	Functional Flow Block Diagram
FOC	Full Operational Capability
FoS	Family of Systems

FOT&E	Follow-On Operational Test and Evaluation
FQR	Formal Qualification Review
FRD	Functional Requirements Document
FRP	Full Rate Production
GFE	Government Furnished Equipment
GFM	Government Furnished Materiel
GFP	Government Furnished Property
H	(1) Section or an RFP or model contract that specifies special contract requirements or provisions
	(2) High Risk
HDBK	Handbook
HSI	human systems integration
I	Section or an RFP or model contract that specifies contract clauses
ICA	Independent Cost Assessment
ICD	(1) Initial Capability Document
	(2) Interface Control Document or Drawing
ICE	Independent Cost Estimate
ICWG	Interface Control Working Group
ILS	Integrated Logistics Support
IMP	Integrated Master Plan
IMS	Integrated Master Schedule
IOC	Initial Operational Capability
IOT&E	Initial Operational Test and Evaluation
IPA	Integrated Program Assessment
IPAT	IPA Team
IPD	Integrated Product Development -- see IPPD
IPPD	Integrated Product and Process Development
IPT	Integrated Product Team
IRS	Interface Requirements Specification
ITO	Instructions to the Offerors
J	Section of an RFP or model contract which lists attachments
JCIDS	Joint Capabilities Integration and Development System
JROC	Joint Requirements Oversight Council
JROCM	JROC memorandum

JTA	Joint Technical Architecture
KDP	Key Decision Point
KPP	key performance parameter
L	(1) Section of an RFP that includes the Proposal Preparation Instructions (2) Low Risk
LCC	Life Cycle Cost
LFT&E	Live-fire Test & Evaluation
LOE	Level Of Effort
LRIP	Low-Rate Initial Production
LRU	Line Replaceable Unit
LSA	Logistics Support Analysis
M	(1) Section of an RFP that includes the evaluation criteria and factors (2) Moderate Risk
MDA	Milestone Decision Authority
MDAP	Major Defense Acquisition Program
MIL-SPEC	Military Specification
MIL-STD	Military Standard
MMD	Mean mission duration
MNS	Mission Need Statement
MOE	Measure of Effectiveness
MS	Milestone
MSSRP	Military Specifications and Standards Reform Program
MTBF	Mean Time Between Failure
NBC	Nuclear, Biological, and Chemical
NBCC	Nuclear, Biological, and Chemical Contamination
NDI	Non-Developmental Item
NSS	National Security System, National Security Space
O&S	Operations and Support
OA	Operational Architecture (as in OA View)
OIPT	Overarching Integrated Product Team
ORD	Operational Requirements Document
OSA	Open System Architecture
OSS&E	Operational Safety, Suitability, and Effectiveness
OT&E	Operational Test and Evaluation (IOT&E and/or FOT&E)

OTA	Operational Test Authority
OV	Operational View
PCA	Physical Configuration Audit
PCO	Procuring Contracting Officer
PDR	Preliminary Design Review
PESHE	Programmatic Environmental, Safety, and occupational Health Evaluation
PM	Program Manager
PPBE	Planning, Programming, and Budgeting Execution process
PPBS	Planning, Programming, and Budgeting System
PPI	Proposal Preparation Instructions
PRR	Production Readiness Review
PWBS	Program or Project Work Breakdown Structure (WBS)
RAA	Responsibility, Authority, and Accountability
RFP	Request for Proposal
SA	System Architecture (as in SA View)
SAF	Secretary of the Air Force
SDD	System Development and Demonstration
SDP	Software Development Plan
SDR	System Design Review
SEIT	Systems Engineering & Integration Team
SEMP	Systems Engineering Management Plan
SERD	Support Equipment Requirements Data (SERD)
SFW	Space Flight Worthiness
SMC	Space and Missile Systems Center
SOO	Statement of (Government) Objectives
SoS	System of Systems
SOW	Statement of Work
SPD	System Performance Document
SPO	System Program Office
SRD	System Requirements Document
SRR	System Requirements Review
SRU	Shop Replaceable Unit
SSA	Source Selection Authority
SSS	System/Subsystem Specification

STAR	System Threat Assessment Report
SV	Systems View
SVR	System Verification Review
T&E	Test & Evaluation
TA	Technical Architecture (as in TA View)
TBD	To Be Determined
TBR	To Be Resolved
TBS	To Be Supplied
TDP	Technical Data Package
TDS	Technology Development Strategy
TEMP	Test and Evaluation Master Plan
TM	Technical Manual
TO	Technical Order
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 (See also DTC, DTUPC)
USD(AT&L)	Under Secretary of Defense (Acquisition, Technology, and Logistics)
USD(C)	Under Secretary of Defense (Comptroller)
USecAF	Under Secretary of the Air Force
WBS	Work Breakdown Structure (see also CWBS and PWBS)

Appendix C—Foundation for the System 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 in Subsection 4.2 above 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[14] 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.

1. 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, roadmaps or other related planning documents,[15]

(b) **Initial Capabilities Document (ICD)** or Mission Needs Statement (MNS),[16]

(c) any Operational Views (OVs) or System Views (SVs) as defined in the **DoD Architecture Framework**,[17] if applicable, and

(d) the Concept of Operations.

(2) System Technical Requirements Document (TRD). A 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

14. For a definition of the pre-systems acquisition phase, see NSSAP 03-01, Figure 1.
15. See CJCSM 3170-01, Enclosure A, for a description of functional area analyses. Other potentially applicable joint planning is also described in CJCSI 3170.01C and CJCSM 3170-01.
16. See DoDI 5000.2, May 12, 2003, Sections 3.2 to 3.5.5 and CJCSI 3170.01C, 24 June 2003, Enclosure A.
17. See the **DoD Architecture Framework, Volumes I and II,** 15 Jan 03. The operational and system views are introduced in Volume I, Sections 3.1 through Section 4. The OV and SV are described in more detail in Volume II, Sections 4 and 5, respectively. SV-1 is intended to depict the functional (or mission) area nodes into which elements of the system will be incorporated or other systems in a family or system of systems (FoS or SoS) of which the system is to be a part. SV-3 shows the same information in matrix format.

Resolved," or "To be Supplied as well as a verification section that identifies verification strategy instead of verification methods. The data in the document is used by the performing activity to initiate the Requirements Analysis of 4.2.1. As the program evolves, the system technical requirements are resolved, incorporated into the requirements baseline, and captured in the system specification.

(3) Applicable Acquisition Decision Memorandum(a)—at least any parts that relate to system requirements, objectives, goals, or tradeoffs to specifically include any guidance on life-cycle cost or affordability, technology readiness levels, schedule, and 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 that the threat assessment should be reviewed and updated as the solution(s) evolve).

(5) Interface **and interoperability** requirements and 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—and applicable standards in the Joint Technical Architecture (JTA)[18] or other interoperability standards.)

(6) Applicability of standards in the[19] DoD Information Technology Standards Registry and compliance to the Global Information Grid.

(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, by planned deliveries under other contracts, or anticipated technology maturation.

(10) For both context and completeness, also review 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) plan-

18. See DoDI 5000.2, May 12, 2003, Section 3.2.1.2 and http://www.disa.mil/main/jta.html
19. See DoDI 5000.2, May 12, 2003, Section 3.2.1.2 and http://www.disa.mil/main/jta.html.

ning documents and include any relevant portions in the SE foundation and the information transmitted to the Contractor(s).

2. 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, Capability Production, or Operational Requirements Document (CDD, CPD, CCPD, C-CPD, or ORD)

(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. – review the current versions of DoDI 5000.2,[20] the NSSAP 03-01,[21] and the Air Force 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[22] as well as handbooks and manuals related to systems engineering to include program management; work breakdown structures; configuration management; interchangeability, flexibility & 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 2nd source procurement); EMI/EMC including electrical referencing & 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

20. See, for example, DoDI 5000.2, May 12, 2003, Enclosure 3 (E3).
21. See, for example, the **NSSAP 03-01**, October 6, Appendix 1 (AP1), AP1.1.7 and the requirements to address ESOH in Enclosures 2 and 5.
22. Contact SMC/AXEM for the current SMC technical baseline.

development including solar arrays, storage, and distribution; electro-explosive and ordnance; metals including dissimilar metals; composites; and structures including load factors and factors of safety)

Note: in some cases, these related areas may indicate additional areas of design constraints that should be added to Subsections 4.1.1, 4.1.2, and/or 4.1.3

(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) Either the level to which vulnerabilities to each threat are to be controlled or the basis (such as trade-off ground rules) by which such levels are to be determined or recommended by the Contractor(s).

(8) Support or sustainment concept or approach or the basis by which the Contractor(s) is/are to develop the concept—identify key stakeholders including the Operator/Users and Air Force Materiel Command (AFMC) personnel.

(9) Training concept or approach or the basis by which the Contractor(s) is/are to develop the concept—identify key stakeholders including the Operator/Users, Air Education and Training Command, and any others responsible for training.

(10) The definition of certification criteria for Operational Safety, Suitability, and Effectiveness (OSS&E) and Space Flight Worthiness (SFW) Certification and required Contractor support to and/or certifications of readiness at Independent, Mission, Flight, and/or Launch Readiness Reviews. (See SMCIs 63-1201, 63-1202, 63-1203, and 63-1204.)

(11) Philosophy, approach, and requirements for 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.

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