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AEROSPACE REPORT NO.
TOR-2005(8583)-3, Rev. A

Systems Engineering Requirements and Products

29 September 2005

Edited by

L. W. PENNELL
Sparta, Inc.

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Office of the Corporate Chief Architect/Engineer
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

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SYSTEMS ENGINEERING REQUIREMENTS AND PRODUCTS

Approved by

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Abstract

This Technical Operating Report (TOR) specifies requirements for the conduct of a complete, integrated systems engineering effort, not a specific systems engineering model or method of implementation. Integration of a comprehensive technical effort will also include requirements from other technical documents selected for contractual implementation to satisfy program requirements and to comply with DOD policy. These requirements provide a robust systems engineering approach that balances total system performance and total ownership costs within the family-of-systems and systems-of-systems context.

This document is intended to govern the execution of systems engineering when levied on contractors as a compliance document. These requirements constitute the government's requirements for an executable contractor systems engineering efforts to assist in defining, performing, managing, and evaluating systems engineering efforts in defense system acquisitions and technology developments. Systems engineering is described in terms of what must be done, not how to do it. The requirements in this document, including those for systems engineering management, are delineated in terms of the required systems engineering tasks, products and the required attributes of those products.

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

This document also provides a reference to the government, or other customers, for analyzing competing contractor proposals and for evaluating the contractor's systems engineering products once on contract. The customer will perform initial tailoring of this document to address appropriate program scope, appropriate program size, and progress within the acquisition life cycle. This TOR 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.

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Foreword

This document is introduced to convey to National Security Space (NSS) systems contractors the government's requirements and expectations for implementing a comprehensive and disciplined systems engineering (SE) program. It is intended that this standard will typically be cited as a compliance standard in NSS Requests for Proposals (RFPs) and contractually baseline the standard in the contract as a compliance standard. This standard was not written with the intent to define the government's responsibilities or roles for implementing a systems engineering process; it is expected that the government will have its own internal processes and practices that complement the contractors' in all of the technical areas defined in the standard.

Specifically, this document defines the government's requirements and expectations for delineating those executable contractor 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 and those products which are an output of the process — not the process itself and the "how to do it." Requirements are defined in terms of the required systems engineering products and the required attributes of those products.

This Technical Operating Report (TOR) constitutes direction to NSS contractors with regard to the execution of systems engineering. Consequently, the objective in writing the document was to specify those critical and essential SE requirements that are necessary for planning and implementing an effective SE program. It is essential that the requirements stated in this standard be clear and concise such that NSS contractors can reasonably price an effort. It is important that the same fundamental requirements are not stated over and over again in slightly different words or in varying degree of detail and "how to" specificity. It is expected that the contractors receiving this report are subject matter experts; this standard was thus not designed to provide tutorial type content. The government will perform initial tailoring of this document to address appropriate program scope for the intended acquisition. This TOR and tailoring, if any, will be made part of all draft and final RFPs along with instructions for contractors to propose further tailoring as part of their proposal submittals.

This document governs the products and output resulting from the conduct of a complete, integrated systems engineering technical effort. There are several systems engineering models currently employed for which this standard should not pose any conflict. An objective in writing this standard was not to drive any contractor away from engineering processes and practices that are effective in their application.

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1. SCOPE

1.1 Document Purpose

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

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

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

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

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

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

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

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

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1.2 Document Organization

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

1. Functional area requirement
2. Required systems engineering products
3. Required product characteristics

Each general requirement stated in the Requirements sections contains the Contractor's requirement for performance of the specific systems engineering function/process as expressed in a "SHALL" statement. Each section entitled "Required Systems Engineering Products" provides a list of products required to comply with the general requirement. The section entitled "Required Product Attributes" describes the characteristics of each required systems engineering product.

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2. Reference Documents

The following documents are referenced in this standard. The order of presentation does not imply an order of precedence.

- National Security Space Acquisition Policy 03-01, 27 December, 2004
- Department of Defense Directive 5000.1, May 12, 2003
- DODI 5000.2, Operation of the Defense Acquisition System, May 12, 2003
- CJCSI 3170.01C, Joint Capabilities Integration and Development System, 24 June 2003
- CJCSM 3170.01, Operation of the Joint Capabilities Integration and Development System, June 24, 2003
- DOD Architecture Framework (version 1), Volumes 1 & 2, 15 January 2003
- DOD 5000.4-M, Cost Analysis Guidance and Procedures, December 1992
- MIL-HDBK-881, Work Breakdown Structure, January 2, 1998
- SMC Systems Engineering Primer & Handbook (2nd Edition), 15 Jan. 2004
- INCOSE Systems Engineering Handbook (version 2.0), July 2000
- Defense Acquisition Guidebook, December 20, 2004
- DOD 5010.12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL)
- MIL-STD-1521B, Technical Reviews and Audits for Systems, Equipment, and Computer Software, 4 June 1985.
- SMCI 63-1202, Space Flight Worthiness, 1 Oct. 2002
- Military Standard-Test Requirements for Launch, Upper Stage, and Space Vehicles (Draft), Aerospace report No. TOR-2003(8583)-1, 19 December, 2002
- MIL -STD-973, Configuration Management, 17 April 1992
- DODD 4630.5, DOD Information Technology Standards Registry, 5 May 2004
- DODI 4630.8, Global Information Grid
- ISO 17666, Risk management, 1 April 2001
- MIL-STD 1543B, Reliability Program
- TMCR 86-01, U.S. Air Force Technical Manual Contract Requirements, 30 March 2004
- Systems Engineering Revitalization Specifications and Standards Implementation Plan and Status – Revision 4, Aerospace report No. TOR-2005(8583)-2, 15 November 2005
- NRO Mission Assurance Standards (MAS) Document (version 1.0), 1 June 2005
- NRO Standards Document (NSDv-2) – Version 2, 4 March 2004.

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3. Definitions

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Cost As an Independent Variable (CAIV) – An approach to the acquisition of military systems in which cost can be treated as a military requirement and cost, schedule, and performance may be traded within the "trade space" between the objective and the threshold.

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

Derived requirements – Requirements not explicitly stated in the capability need that 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 – An iterative decision-making process that produces plans by which resources are converted into products or systems that meet system requirements.

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

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

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

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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.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Integrated architecture (for interoperability) – A structure based on the definition of architecture as a structure of components, their relationships, and the principles and guidelines governing their design and evolution over time. Thus the integrated architecture shows "components" and their relationship and needed capabilities for such key military capabilities as interoperability and sustainment.

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

Integrated Master Schedule (IMS) – The schedule showing the time relationship between events, significant accomplishments, and the detailed tasks required to complete the contract 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). 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.

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

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

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.

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

Interface Control Document; Interface Control Drawing (ICD) – Drawing or other documentation that depicts interface designs or elements of interface designs that satisfy interface requirements.

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

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

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

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

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

Life cycle cost (LCC) – The total cost to the government, both sunk and anticipated, of acquisition and ownership of the system over its useful life. It includes the cost of research, development, test and evaluation; procurement (to include production testing, deployment, and support to IOT&E); operations and 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).

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

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

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

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government entity or (2) 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.

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.

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

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

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

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

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

Product configuration baseline, product baseline – The initially documented and approved update to the design release baseline for one or more system products after confirmation (1) of qualification that the product design satisfies all performance and functional requirements and constraints in the current allocated and design release baselines, (2) that the as-built, as-coded, or as-integrated product is accurately reflected in the baselines, and (3), for hardware

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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.

Qualification – (1) For hardware, the verification that a hardware item or higher level of integration, together with its embedded software, meets all requirements and constraints during the worst-case environmental and operating conditions anticipated over its life cycle; (2) for software, the verification that a software unit meets all requirements and constraints using operationally representative data in an operationally representative configuration.

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

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

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

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

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

Requirements baseline – The documented, validated, and approved system-level (top-level) verifiable and allocable functional and performance technical requirements and design constraints, their allocation or assignment to the 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 – The uncertainty of attaining a requirement, goal, or objective pertaining to technical performance, schedule, or cost and the consequences of not attaining it.

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.

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

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

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

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

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

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

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

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

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

System concept – A rudimentary or unfinished design, used for preliminary assessments of system effectiveness, cost, schedule, or risk, which provides 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 database supports two-way traceability from the source of the requirements baseline to the preliminary allocated baseline and from any element to the rationale for that element, (5) the assessment that the evolving allocated baseline can lead to a design that will satisfy the requirements baseline, (6) the preliminary physical hierarchy, the

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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 database documenting or demonstrating that these systems engineering requirements have been satisfied.

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

System product – A separately identifiable portion of a system other than personnel, whether delivered or not, to include hardware, software, firmware, process, government facility/equipment or modification of an existing government facility/equipment, modification to existing equipment or property, document, manual, drawing, instructions, data, or combination thereof. Services 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 Defense Intelligence Agency (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 nonlethal threats against the system and the threat environment in which the system will operate.

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

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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 war fighting 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 – As a process, service, function, or activity, an interdisciplinary effort to iteratively and recursively (1) support the evolution of, first, the integrated architectures, roadmaps, capability assessments, and Initial Capabilities Document (ICD), and then later, the Capabilities Development Document (CDD) and Capabilities Production Document (CPD) to guide the development program, (2) translate the needed capabilities and objectives into, first, a requirements baseline, second, an allocated baseline, third, a design release baseline, and, finally, a product configuration baseline 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, (3) maintain those baselines over the life cycle of the system, (4) assess compliance with the baselines as development evolves, and (5) verify that the baselines have been met by products built, coded, bought, and integrated IAW the design and then support the validation (through OT&E) that the needed capabilities have been provided.

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

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

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

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

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

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

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

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

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

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

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

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

Total Ownership Cost – 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 database) 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. Can be used as the basis for selecting less capability in one area in order to achieve a more balanced overall system result.

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

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

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

Validation – (1) For a baseline, the demonstration that it has its required attributes, that any assumptions necessary in its development are valid (i.e., acceptable to the customer), and that the effectiveness of the emerging system design can affordably satisfy the system technical requirements and constraint; (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 – Confirmable, capable of being tested (verified or falsified) by experiment or observation.

Verification – The process that confirms that the system element meets the design-to or build-to specification.

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

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

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4. General Requirements

This section defines the required systems engineering processes, tasks, and products across the system life cycle for any system, to include new development, upgrade, modification, resolution of deficiencies, or development and exploitation of technology. These tasks are to be performed throughout the system life cycle; however, the outputs produced by these tasks will be highly dependent on their position in the life cycle.

The systems engineering process is an iterative process starting with requirements analysis, proceeding to functional (logical) analysis and requirements allocation, and then to design solution (synthesis) as depicted in Figure 4-1. Iteration can occur between the activities or via the verification and validation feedback loops. Systems analysis and control is to be performed throughout the systems engineering process. The systems engineering process also must support top-down recursions to develop the system at increasingly detailed levels and bottoms-up recursion during assembly/ integration. The recursive nature is further depicted in the "VEE" diagram of Figure 4-2. Both generic processes depicted in Figures 4-1 and 4-2 typically apply to the development of complex systems.

Section 4 defines the general requirements corresponding to the systems engineering (SE) activities presented in Figure 4-1. This SE activity flow is further expanded in Figure 4-3 to provide a cross-reference between the standard SE activities and the requirements presented in this document.

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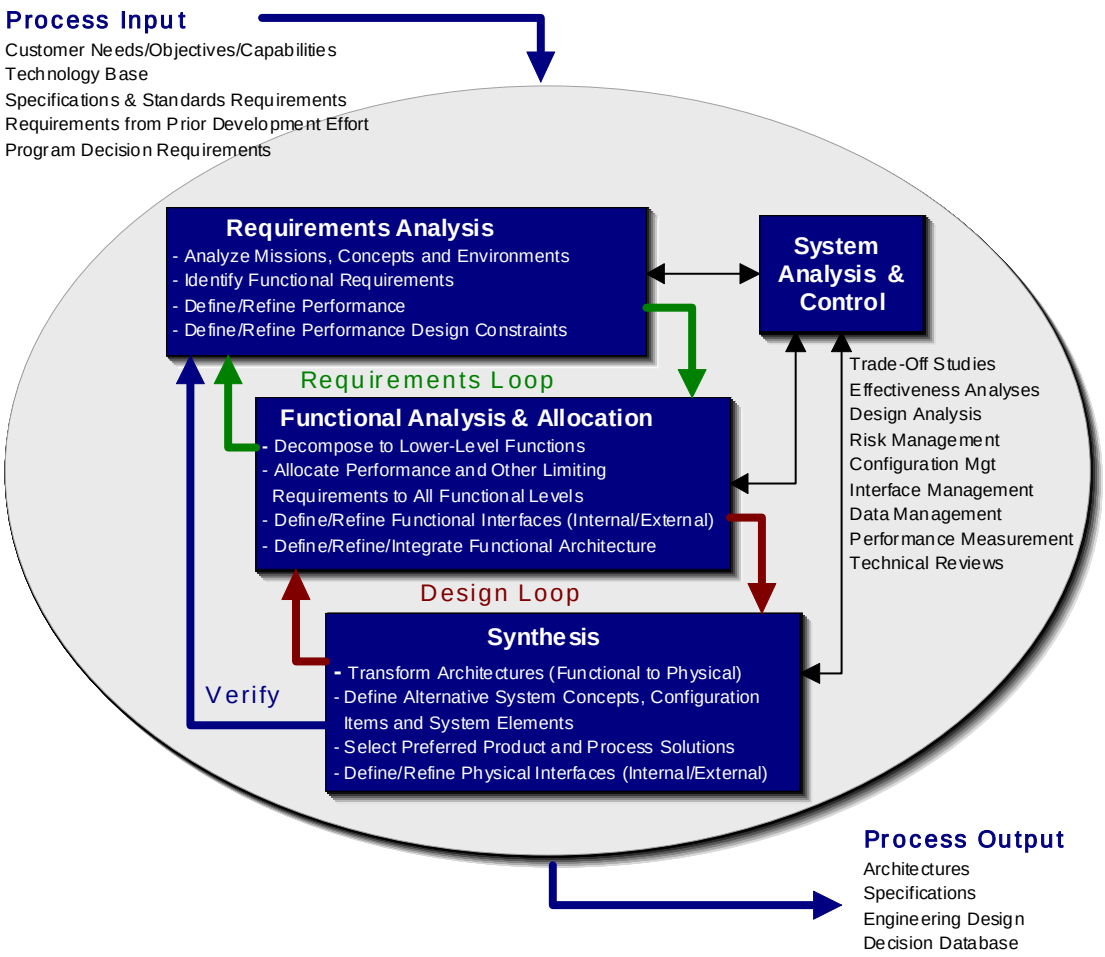

Figure 4-1. Example System Engineering Process.

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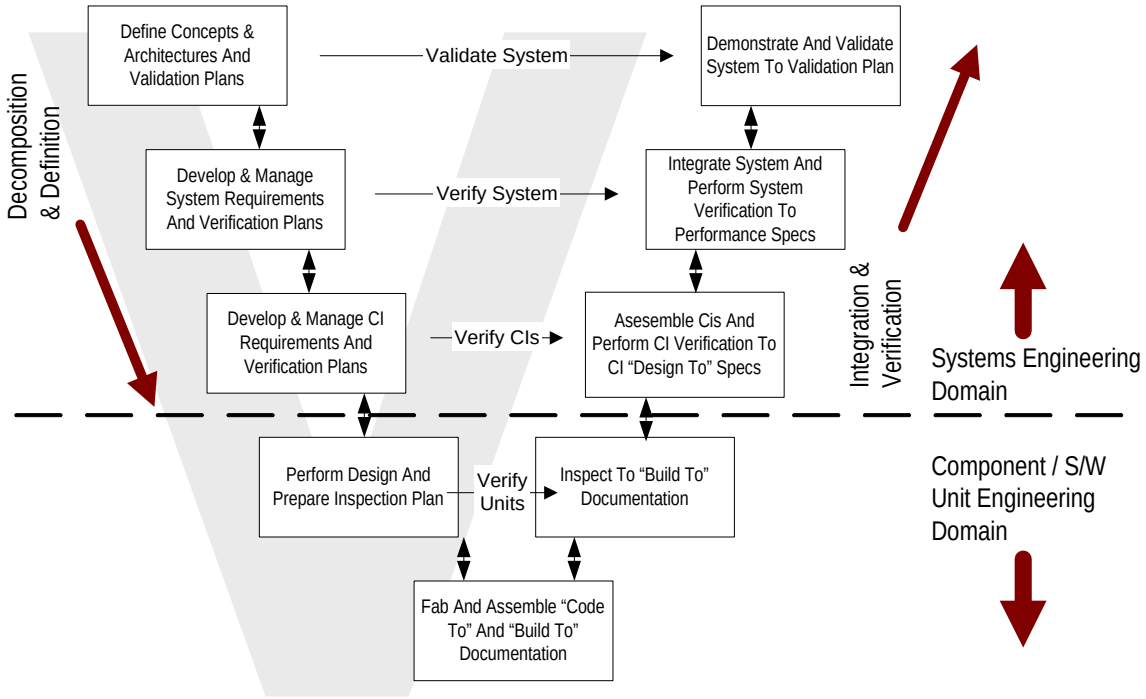

Figure 4-2. Systems Engineering Process described by a "VEE" diagram.

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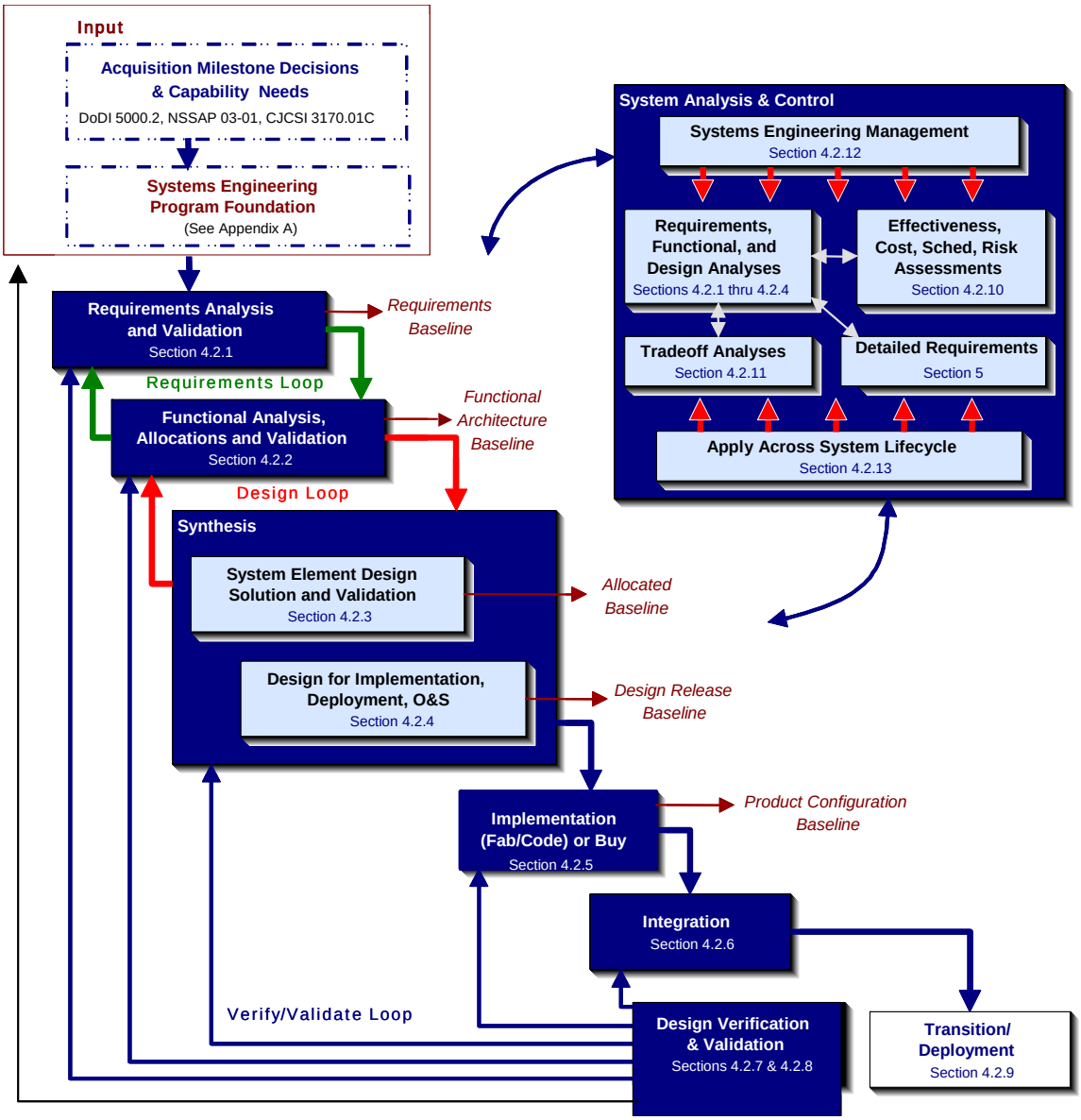

Figure 4-3. Relationship between minimum essential systems engineering requirements and baselines.

4.1 System Engineering Process Application

a. The Contractor SHALL apply a comprehensive systems engineering process that is mutually agreeable between the contractor and contracting agency.

b. The Contractor SHALL document the comprehensive systems engineering process and management plan to be used throughout the procurement, and update as required.

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

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4.1.1 Support to the Capability Needs Process

a. The developer SHALL support the customer in developing, refining, and updating, for all stakeholders:

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

   (2) The architectural products, including the applicable operational and systems views as directed by the customer in accordance with (IAW) the DOD Architecture Framework (current version).

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

   (4) The Operational Scenarios and Concept of Operations (CONOPS) for the operational and system concepts under consideration to fill the capability gaps.

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

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

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

   (8) Sustainment strategies

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

   (10) Operational test planning.

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

4.1.2 System Level Constraints, Concepts and Architectures

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

4.1.2.1 Required System Engineering Products

a. Validated, approved and maintained integrated architectural views, as defined by the Department of Defense Architecture Framework (DODAF), that characterize interrelationships between the system and its elements and the interoperability of the system with other system, units and forces

b. Source and engineering basis, including trade-offs or other analysis for each architectural selection

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4.1.2.2 Required Product Attributes

a. The architecture products:

1. Represent the system and its integration sufficiently to achieve the desired operational capability.
2. Trace to the allocated functional and physical elements from which the architectural elements are derived.
3. Trace to the capabilities for which the system is being designed and to the missions for which it is intended. Traceability should be maintained in both directions; top-down and bottom-up to identify requirements without parents and requirements that don't spawn children. This traceability between mission, capability, and architecture characteristics is to be maintained and kept up to date at all times.
4. Include standards used to develop the Operational and Systems Views that are selected to sufficiently develop, integrate, and maintain the required architecture products using the guidance defined in DOD Architecture Framework Version 1.0, Volumes I and II.
5. Include standards used to form the Technical Views of the integrated architectures that are selected from those contained in the current approved version of the Joint Technical Architecture.
6. Provide an integrated architecture for interoperability that extends and is consistent with any architectural views provided by the customer (or otherwise identified by the developer and sanctioned in writing by the customer) and the capability needs or operational capability requirements document as conditioned by any milestone or key decision point decisions.

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4.2 Systems Engineering Requirements

4.2.1 Requirements Analysis and Validation

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

4.2.1.1 Required System Engineering Products

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

b. System architecture and requirements traceability matrix(es)

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 Product Attributes

a. The requirements baseline:

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

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

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

   (4) Includes system interoperability needs, including any interface constraints defined in operational/system views depicted in the DOD Architecture Framework.

   (5) Includes all functional and performance requirements and constraints and those imposed by each specialty function (see Subsection 5.1).

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

   (7) Is the result of decision trade studies (tradeoffs) to balance system effectiveness, life cycle cost, schedule, risk, and the potential for evolutionary growth.

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

      (a) Compliance with the above attributes

      (b) Two way traceability between the requirements baseline and the requirements source

      (c.) That the design of system concept represents a balanced solution including system effectiveness, life cycle cost, schedule, risk, and evolutionary growth potential issues.

   (9) Is documented in a system specification or TRD.

b. The system architecture and requirements traceability matrices:

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

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

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

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

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

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

4.2.2 Functional (Logical) Analysis

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

4.2.2.1 Required System Engineering Products

A logical solution representation (functional architecture)

4.2.2.2 Required Product Attributes

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

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

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

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

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

(5) Includes the relationships to the physical solution and be documented in the decision database.

(6) Includes the definition of both the internal and external interfaces, and addresses the physical implementation, as well as the logical issues such as data formats, data semantics, etc.

(7) Is validated through customer involvement to ensure:

(a) Compliance with above attributes.

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

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

4.2.3 System Element Design Solution and Validation

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

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 (hardware and software), computer software unit, and part

4.2.3.2 Required Product Attributes

a. The allocated baseline:

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

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

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

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

(5) Includes all interfaces and addresses how the interface will be implemented, as well as the logical issues such as data formats, data semantics, etc.

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

4.2.4 Design for Implementation, Deployment, Operations, and Support

The Contractor SHALL design the products that constitute the system to include implementation (fabrication and code) and sustainment assets and develop the associated required systems engineering documentation with the attributes specified in this document.

4.2.4.1 Required System Engineering Products

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

a. The basis for each design selection.

4.2.4.2 Required Product Attributes

a. The design release baseline:

(1) Fully satisfies the allocated baseline over the system life cycle.

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

(3) Is designed to realize interoperability.

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

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

(6) Incorporates Non-Developmental Items (NDI), Commercial Off-the-Shelf (COTS), precedented designs, technologies at Technology Readiness Level (TRL) 6 or above, and modular, open systems approaches when such alternatives can satisfy the requirements and allocated baselines and the resulting design balances system effectiveness, life cycle cost, schedule, risk, and potential for evolutionary growth.

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

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

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

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

(11) Is validated through customer involvement to ensure:

(a) Compliance with above attributes.

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

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

b. The basis for each design selection:

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

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

4.2.5 Implementation

The contractor SHALL build, code, or buy the products that comprise the system to include the implementation (fabrication and code) and sustainment assets.

4.2.5.1 Required System Engineering Products

Product Configuration Baseline

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4.2.5.2 Attributes

The Product Configuration Baseline:

a. Has been fabricated or coded in a manner that fully satisfies the Design Release Baseline over the system life cycle.

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

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

4.2.6 Integration

The Contractor SHALL perform integration of lower-level elements (such as components, software units, configuration Items, Computer Software Configuration Items, and systems) into the next-higher level and develop the associated required systems engineering products with the product attributes specified in this document. Integration activities are performed with approved assembly/integration and verification procedures at each level of the build-up.

4.2.6.1 Required Systems Engineering Products

a. Assembly/integration and verification procedures

b. Discrepancy reporting, causal analysis and corrective action procedure

4.2.6.2 Required Product Attributes

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

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

   (2) Assembly/integration and verification of component/software unit interfaces.

   (3) Assembly/integration and verification of hardware/software item interfaces.

   (4) Integration/verification of system & support interfaces.

b. Discrepancy reporting, causal analysis and corrective action procedure is integrated with the assembly and verification procedures.

4.2.7 Design Solution Verification

The Contractor SHALL verify the system's design and development to confirm that the system meets all documented requirements, and develop the associated required systems engineering products with the product attributes specified in this document.

4.2.7.1 Required System Engineering Products

a. Documented System Verification Program

b. Verification Results

c. Design Qualification Data

d. Acceptance Verification Data

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

4.2.7.2 Required Product Attributes:

a. The System Verification Program:

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

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

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

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

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

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

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

(8) Maintains a record of all discrepancies.

b. Verification Results:

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

(2) Use design analysis and simulation as a complement, not replacement, for demonstration and test.

c. The Design Qualification Data:

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

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

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

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

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d. The acceptance verification data:

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

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

e. The product configuration baseline:

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

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

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

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

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

4.2.8 Design Solution Validation

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

4.2.8.1 Required System Engineering Products

a. System Validation Plan

b. System Validation Data

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4.2.8.2 Required Product Attributes

a. The System Validation Plan:

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

(2) Identifies any computers and other resources needed for such efforts as well as any needed Government-Furnished Equipment (GFE) and Government-Furnished Information (GFI).

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

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

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

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

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

b. System Validation Data:

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

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

(3) Documents any discrepancies between the:

(a) Product configuration baseline and stakeholder expectations

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

(4) Includes 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.

(5) Includes support to the System Readiness Reviews to include the Mission Readiness Review, Flight Readiness Review, and the Post Flight Reviews.

(6) Supports IOT&E, including:

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

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

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

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

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

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

4.2.9 Transition (Deployment) Analysis and Assessment

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

4.2.9.1 Required System Engineering Products

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

4.2.9.2 Required Product Attributes

a. Deployment analyses and assessments address:

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

(2) Operational and maintenance facilities and equipment requirements.

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

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

(5) Early deployment of training items and personnel.

(6) Initial provisioning and spares.

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

(8) Site transition requirements.

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

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

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

4.2.10.1 Required Products

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

b. Documented system effectiveness assessments and reports

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c. Documented cost assessments and reports

d. Documented schedule assessments and reports

e. Documented risk assessments and reports

4.2.10.2 Required Product Attributes

a. The documented process:

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

(2) Identifies for each assessment to be performed:

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

(b) Quantified objectives and goals.

(c) Alignment measurements, measurement objectives, and analyses activities with required capabilities, system technical requirements, and constraints.

(d) The elements of cost, schedule, and risk that could be affected by the factors considered in each tradeoff required by the Physical Solution Verification process.

b. Each assessment of system effectiveness:

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

(2) Surfaces deficiencies for Key Performance Parameters (KPPs) and ensures that the traceability between the MOEs, MOPs, KPPs, and TPMs is maintained.

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

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

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

(6) Compares the applicable elements of the integrated architecture for interoperability to the Joint Technical Architecture (JTA).

(7) Includes Environmental Analysis and Impact.

c. Each assessment of cost:

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

(2) Applies methodologies that are accepted NSS-/industry-wide.

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

(4) Employs simulation where cost effective.

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

(6) Addresses cost and schedule risk.

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

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

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

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

(d) Identify the economic consequences of solution alternatives.

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

d. Each assessment of schedule:

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

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

e. Each assessment of risk:

(1) Develops objective text descriptions identifying each risk.

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

(3) Specifies the possible consequences.

(4) Proposes corrective actions to mitigate the risk.

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

4.2.11 Tradeoff Analyses

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

4.2.11.1 Required System Engineering Products

a. Documented trade-off analyses

4.2.11.2 Required Product Attributes

a. Documented tradeoff analyses include:

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

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

(3) Documented plans and results.

4.2.12 Management of the Systems Engineering Process

The Contractor SHALL manage the systems engineering 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, and develop the associated required systems engineering products with the product attributes specified in this document.

4.2.12.1 Planning

The Contractor SHALL plan all aspects of the systems engineering effort.

4.2.12.1.1 Required System Engineering Products

a. Contract Work Breakdown Structure (CWBS)

b. The systems engineering accomplishments, accomplishment criteria, and narrative in the Integrated Master Plan (IMP); tasks in the Integrated Master Schedule (IMS); and work packages in the Earned Value Management System (EVMS), and such other specific plans (such as tradeoff plans) as may be needed to achieve the attributes required above.

4.2.12.1.2 Required Product Attributes

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

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

(1) Reflect all technical execution and management efforts.

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

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

4.2.12.2 Monitoring

The Contractor SHALL monitor the progress against all planning to:

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

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

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

d. Monitor or mitigate each risk.

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4.2.12.2.1 Required System Engineering Products

a. Documented Systems Engineering Assessments linked in the decision database to the initial plans, the results of each iteration for which it is a part to include tradeoffs and other assessments, the decisions made and their justification, and the actions taken

4.2.12.2.2 Required Product Attributes

a. Each documented assessment includes:

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

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

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

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

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

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

4.2.12.3 Decision Analysis

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

4.2.12.3.1 Required System Engineering Products

a. Documented and implemented decisions

b. Maintained baselines and functional architecture

4.2.12.3.2 Required Product Attributes

a. Documented and implemented decisions are:

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

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

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

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b. Maintained baselines and functional architecture includes:

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

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

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

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

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

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

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

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

4.2.12.4 Risk Management

The Contractor SHALL establish and implement a risk management program, and develop the associated required systems engineering products with the product attributes specified in this document.

4.2.12.4.1 Required Products

a. Risk Management Plan

b. Risk Watch List

4.2.12.4.1.1 Required Product Attributes

a. The Risk Management Plan:

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

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

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

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

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

(6) Quantifies risks, including risk levels, in terms of the likelihood of occurrence and the severity of their impacts on cost (including life-cycle costs), schedule, and performance.

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Includes design, cost, and schedule uncertainties and sensitivity to program, product, and process assumptions.

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

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

(9) Addresses how technology refresh will be accomplished.

(10) Defines sensitivity of interrelated risks.

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

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

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

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

b. The Risk Watch List:

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

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

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

4.2.12.5 Configuration Management

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

4.2.12.5.1 Required System Engineering Products

a. Documentation of configuration management process

b. Assessments of change control implementation

4.2.12.5.2 Required Product Attributes

a. The documented configuration management process:

(1) Is based on an appropriate military or commercial standard (such as MIL-STD-973 or ANSI/EIA 649A).

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

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

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

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

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

b. Assessments of change control implementation:

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

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

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

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

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

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

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

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

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

4.2.12.6 Interface Management

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

4.2.12.6.1 Required System Engineering Products

a. Interface definition documentation

4.2.12.6.2 Required Product Attributes

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

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

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

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

(4) Ensures that all interface requirements are verified.

4.2.12.7 Data Management

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

4.2.12.7.1 Required System Engineering Products

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

4.2.12.7.2 Required Product Attributes

a. The data products:

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

(2) Provide data correlation and traceability among requirements, designs, solutions, decisions, and rationale.

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

(4) Are responsive to established configuration management procedure.

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

4.2.12.8 Technical Management of Subcontractors/ Vendors

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

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

4.2.13 Application Across The Life Cycle

The Contractor SHALL integrate their systems engineering process with the design review process specified by contract (see Table 4-1).

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Table 4-1. Development stages for increasing accuracy and completeness of the program baselines

Nominal DoDI 5000.2 Phase[1]	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 4.2.1	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	–
System Integration		PDR	Maintained	Approved IAW 4.2.3	Draft – basis for assessment to support allocated baseline validation	–
		CDR	Maintained	Maintained	Approved IAW 4.2.4 build, buy, code, author, and integrate developmental 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

[1] 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.

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5. Detailed Requirements

This section describes systems engineering tasks that SHALL be applied to a specific program based on the system and program requirements. Tailored program-specific requirements will be specified in the solicitations and invoked by the contract.

5.1 Specialty Engineering Activities

The Contractor SHALL, for each specialty area listed below**:**

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

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

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

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

5.1.1 Parts, Materials and Processes (PMP)

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

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

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

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

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

f. Space systems radiation hardening design solutions established.

5.1.2 Structures

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

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

c. Verification methods for each structural requirement are defined.

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

e. Technical risk mitigation approaches are defined.

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

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

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

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

5.1.3 Manufacturing

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

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

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

d. Alternative designs and capabilities of manufacturing are evaluated.

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

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

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

h. Manufacturing and producibility requirements and constraints are defined.

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

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

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

5.1.4 Quality Engineering

a. Qualified inspection/test processes demonstrating effectiveness.

b. Capable processes established for:

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

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

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

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

d. Quality Assurance schedules established to concurrently support procurement, manufacturing, integration, and test processes.

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

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5.1.5 Test

a. Design test requirements defined, allocated and traceable to system level requirements, including risk assessments.

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

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

d. Test tools, test equipment (including Special Test Equipment)/software, diagnostics software, modeling and simulation requirements defined, allocated, and traceable to system components.

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

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

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

h. Approach to provide test support and documentation to design changes on hardware and software developed.

5.1.6 Survivability

a. System level survivability requirements defined, allocated, baselined and traceable to the system level requirements.

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

c. Approach for verification of system level survivability/operability requirements identified.

d. Test facilities capable of simulating threat environments identified.

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

f. Threats defined and mitigation strategies defined.

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

h. System/threat interaction analysis performed.

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

5.1.7 Environmental, Safety and Occupational Health (ESOH)

a. System level ESOH requirements defined, allocated, baselined and traceable to the system level requirements:

   (1) Hazards identified.

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

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(3) Mitigation decisions evaluated.

(4) Residual risk acceptance evaluated.

(5) Current mitigation efforts assessed.

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

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

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

d. Containment program developed, including procedures for safe use and disposal.

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

5.1.8 Contamination

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

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

(2) Any needs for new or upgraded facilities

(3) Shipping and prelaunch operations

b. Cleanliness challenges identified and solutions proposed, including:

(1) Uncleanable materials

(2) Solvent incompatability

(3) Mission-unique requirements to launch vehicle

(4) High outgassing materials

c. Heritage analysis complete demonstrating that pre-launch cleanliness requirements can be met and that overall end of life (EOL) requirements can be met.

5.1.9 Mass Properties

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

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

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

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

f. Balance weight locations defined. Provisions for balance weight installation ensured.

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

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5.1.10 Logistics

a. Logistics requirements defined, allocated, baselined, and traced to systems requirements. Logistics Management Information (LMI), Life Cycle Cost (LCC) analysis with a discussion of risks and any risk reduction or control included for the following logistics areas:

(1) Design Interface – System Reliability, Maintainability, Availability, Survivability, including hardness and unique characteristics

(2) Support Concepts/Maintenance Plan – Initial and steady-state support; implementation and transition schedule at organizational and depot level; warranties and SORAP

(3) Manpower and Personnel – Operations, Maintenance (hardware and software), and training support personnel

(4) Supply Support – Support concept for initial and steady state, sparing requirement to support Concept of Operation

(5) Support Equipment and Simulators – Common and specialized organizational and depot support equipment, and system level simulators and trainers

(6) Training and Training Support – Initial and follow-on training, equipment, documentation and facilities; student requirements

(7) Technical Data – Engineering Drawings and Technical Orders; data rights, technical manual contract/delivery requirements

(8) Computer Resource Support – Software and database maintenance, facilities, equipment, COTS and documentation

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

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

5.1.11 Human Systems Integration (HSI)

a. HSI system-level requirements, including derived requirements, developed, allocated, and traced to the appropriate segment-level requirements.

b. HSI criteria (e.g., human performance and human error rate impacts on space system performance and end-to-end task timelines) modeled/measured and assessed.

c. Impact of human-in-the-loop operations or maintenance on total system performance assessed.

d. HSI considerations included as a part of all applicable qualification testing and verification plans.

e. HSI considerations assessed in the selection, integration, and design options for COTS or purpose-built hardware and software

f. Processes identified to provide HSI and system design input to logistics products development (e.g. training, O&M manuals).

Human performance considerations integrated into all modeling/simulation efforts for system segments/elements that include human-in-the-loop operations or maintenance.

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5.1.12 System Security

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

b. System security requirements defined, including system specific threats and compliance with applicable DOD, national, and international system security policies.

c. System security architecture and management plan documented.

d. Security design, including constraints and trade-offs, detailed; cryptography plans coordinated with the National Security Agency.

e. Certification and accreditation process activities coordinated.

f. Verified that protection mechanisms satisfy security requirements and that appropriate authorities (DOD, national, and international approving authorities) have approved residual security risks.

5.1.13 Reliability

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

   (1) Parameters and limits defined at this level and provided within the System Specification

   (2) Reliability requirements reviewed against functional requirements, customary design practices

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

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

   (2) Source selection and vendor control procedures

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

   (4) Derating and margins of safety

   (5) Fault coverage

   (6) Single point failure

   (7) Redundancy/single string

c. Reliability Program Plan and Risk Management Plan developed for final top-level space system

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

5.1.14 Electromagnetic Interference and Compatibility (EMI/EMC)

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

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

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

   (3) Return of power on spacecraft structure.

   (4) Unshielded or untwisted or unpaired wires.

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

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

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

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

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

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

(11) All first flight/first use EMC parts

(12) All cryo-cooled sensor EMC designs

(13) All EMC requirements with negative margin

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

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

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

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

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

5.1.15 System Safety

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

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

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

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

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

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

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

c. Catastrophic risks eliminated.

d. Critical hazards minimized.

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5.2 System/Cost Effectiveness

5.2.1 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.

5.2.1.1 Required System Engineering Products

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

5.2.1.2 Required Product Attributes

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

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

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

   (3) Joint and combined operations.

   (4) Modes of operational deployment and employment.

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

5.2.2 Supportability Analysis and Assessment

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

5.2.2.1 Required System Engineering Products

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

5.2.2.2 Required Product Attributes

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

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

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

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

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

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5.2.3 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.

5.2.3.1 Required System Engineering Products

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

5.2.3.2 Required Product Attributes

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

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

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

5.2.4 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.

5.2.4.1 Required System Engineering Products

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

5.2.4.2 Required Product Attributes

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

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

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

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

5.2.5 Environmental Analysis and Impact Assessment

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

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5.2.5.1 Required System Engineering Products

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

5.2.5.2 Required Product Attributes

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

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

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

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

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

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

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

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6. Notes

6.1 Intended Use

This section contains information for reference only.

The primary purpose of this document is to be specified by the government on space system development contracts as a compliance document. Therefore, the requirements herein are intended to be Contractor requirements. This document, however, can be used by the government as a guide to assist in systems engineering planning in terms of the required systems engineering efforts. Programs for which a government activity plays a "contractor" role should implement this standard under a "contract" to the tasking government activity. A single, integrated set of technical tasks should be developed. This can be accomplished by integrating all the tasks in the contract's Statement Of Work (SOW), tailoring this document to include tasks from other standards selected for contractual application, executing the complete, integrated task set via the Ssytems Engineering Management Plan (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 used by the government as follows:

a. For defining the government's requirements for systems engineering in a Request For Proposal (RFP) or Contract. Toward this end, the requirements in this section can be applied by tailoring the requirements in Subsection 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, NSS 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. 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. The requirements herein 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.*[2]
>
> *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.*[3]

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[2]. DoDD 5000.1, **The Defense Acquisition System**, May 12, 2003, Section E1.27
[3]. DoDI 5000.2, **Operation of the Defense Acquisition System**, May 12, 2003, Section 3.9.2.2

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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 Systems Engineering—Concept

Systems Engineering (SE) is the interdisciplinary approach for encompassing the entire set of scientific, technical, and managerial efforts needed to provide a set of life-cycle balanced system solutions that satisfy customer needs. Throughout this standard, "balanced" refers to system requirements and/or the corresponding design for which the capabilities to be provided, cost, schedule, risk, and potential for evolutionary growth have been assessed and found to be acceptable in the context of the program that is to satisfy the requirements. The SE process is an iterative, disciplined method that includes requirements analysis, requirements allocation, design synthesis, and technical management processes. This process takes place over the entire life cycle, from needs definition to system disposal and applies to all levels of acquisition from Systems of Systems (SoS) to individual platforms, systems, subsystems and components.[4] 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 a reasonable range of 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.

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

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The first is that of a series of discrete steps occurring sequentially over time. Here, work products are successively refined through various control gates, such as technical reviews or acquisition phases. The second perspective is that a set of technical activities 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 pertain 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/software solution can be implemented.

Throughout this iterative process, the outputs of technical activities must be integrated and reviewed at the control gates occurring at discrete points in time. These reviews are part of the contract management activities that ensure that time and budget are being well spent, and that progress is sufficient to ensure that the required capabilities will be delivered in a timely and cost-effective manner. Thus, a disciplined acquisition approach is achieved. The work products are matured over control gates, as 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 much iteration of technical activities is needed for successful system acquisition. For example, a relatively simple system (e.g., a single black box to be installed on a weapon system) will likely require fewer decomposition levels and technical activity iterations than would the whole weapon system. Likewise, a purely software system would likely have different control gates than would a hardware and software system.

Systems engineering supports the DOD acquisition process, as codified in DODD 5000.1, the DODI 5000.2, the CJCSI 3170, the NSSA 03-01, Directive 7 and related documents. These documents: (1) 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.

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 processes are implemented. Systems engineering data requirements for contractor(s) need to be established during preparation of the Request for Proposal and

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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.

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 that add unnecessary costs, data, and any factors that do not add value to the process or product should be eliminated. Tailoring takes the form of deletion (removal of tasks not applicable), alteration (modifying tasks to more explicitly reflect the application to a particular effort), or addition (adding tasks to satisfy program requirements). Tailored requirements and task statements may be used in preparing solicitation documents as well as by offerors in response to a draft Request for Proposal. MIL-HDBK-248 provides additional tailoring guidance.

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6.3.1 Tailoring Considerations

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

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

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. Each has different emphasis regarding up-front versus follow-on effort, and the degree of system definition required by the various acquisition milestones.

6.3.1.2 Use of Evolutionary Acquisition[5]

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 Systems6

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

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

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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 '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.[7] 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 for which the functional requirements change even as the environment remains stable are poorly designed; i.e., the requirements did not accurately capture the capabilities needed in the first place.

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

[7] 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

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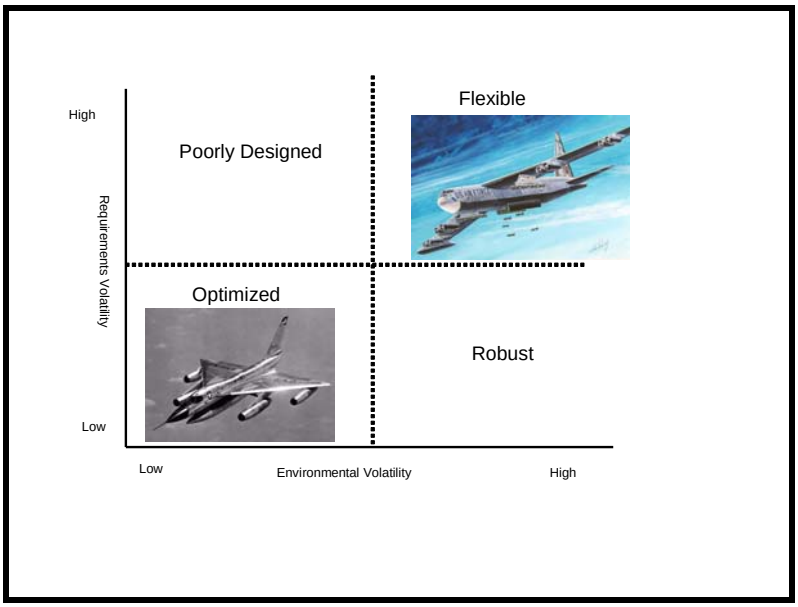

Figure 6-1. Flexible, robust, and optimized systems.

6.5 Evolutionary Acquisition

The DOD has recently been emphasizing evolutionary acquisition (EA). EA is described in the Defense Acquisition Guidebook (DAG) as the preferred DOD strategy for rapid acquisition of mature technology for the user. An evolutionary approach delivers capability in increments, recognizing, up front, the need for future capability improvements. The objective is to balance needs and available capability with resources, and to put capability into the hands of the user quickly. The success of the strategy depends on consistent and continuous definition of requirements, and the maturation of technologies that lead to disciplined development and production of systems that provide increasing capability towards a materiel concept.[8]

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.

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

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

- Detailed requirements and specifications are developed for the current spiral or increment. Implementation that is to occur after this spiral has much less detailed requirements. In the case of a spiral effort, only the most general requirements may be known for future spirals.
- Plans for growth with available bandwidth, electrical power, HVAC, etc. so that future functional requirements can be accommodated.
- The Test and Evaluation Master Plan (TEMP) is tailored for the current spiral.
- The Integrated Logistics Support Plan (ILSP) accounts for multiple versions of the same system since systems fielded in different spirals or increments will be somewhat different. Alternatively, a decision may be made to modify all systems so that they comply with some standard.

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Appendix A — 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 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[9] contract phases including support to the definition of capability gaps that must be filled by materiel programs, analysis of materiel approaches, analysis of alternatives, system concept selection, or development of a statement of capability needs by the operators and users as well as for all subsequent acquisition contract phases. The second list applies to the additional foundation that usually applies to acquisition contract phases.

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

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

(a) Any functional (or mission) area analyses, plans, concepts, roadmaps or other related planning documents[10].

(b) Initial Capabilities Document (ICD) or Mission Needs Statement (MNS)[11].

(c) Any Operational Views (OVs) or System Views (SVs) as defined in the DOD Architecture Framework,[12] if applicable.

(d) The Concept of Operations.

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

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

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

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[9]. For a definition of the pre-systems acquisition phase, see NSSAP 03-01, Figure 1.

[10]. 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.

[11]. DoDI 5000.2, May 12, 2003, Sections 3.2 to 3.5.5 and CJCSI 3170.01C, 24 June 2003, Enclosure A.

[12]. 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.

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(5) Interface/interoperability requirements or constraints imposed by other systems with which the solution must operate or share a boundary (such as the interface between launch and satellite system, physical and functional characteristics of electrical, RF, and software links to other systems, including that for telemetry and control, interfaces with systems or components supplied by associate Contractors, interfaces with facilities, or interfaces with other systems in a family or system of systems—the latter may be covered to a degree in the SVs listed above—and applicable standards in the Joint Technical Architecture (JTA)[13] or other interoperability standards.)

(6) Applicability of standards in the DOD Information Technology Standards Registry [14] 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, the latest Joint Vision, DOD Strategic Plan or DOD Quadrennial Defense Review (QDR), applicable Joint Operations Concepts, and analysis of doctrine, organization, training, materiel, leadership, personnel, and facilities (DOTMLPF) and other related joint, DOD, and service (component) planning documents and any relevant portions in the SE foundation and the information transmitted to the Contractor(s).

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

(1) Capability Development, 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., including current versions of DoDI 5000.2,[15] the NSSAP 03-01,[16] and the Air Force (or other agency) Policy Directives and associated Instructions in each of these areas.

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

(5) Other specifications and standards in the SMC technical baseline[17] as well as handbooks and manuals related to systems engineering to include program management; work breakdown structures; configuration management; interchangeability, flexibility and

[13]. DoDI 5000.2, May 12, 2003, Section 3.2.1.2 and http://www.disa.mil/main/jta.html
[14]. DoDI 5000.2, May 12, 2003, Section 3.2.1.2 and http://www.disa.mil/main/jta.html.
[15]. DoDI 5000.2, May 12, 2003, Enclosure 3 (E3).
[16]. NSSAP 03-01, October 6, Appendix 1 (AP1), AP1.1.7 and the requirements to address ESOH in Enclosures 2 and 5.
[17]. Contact SMC/AXEM for the current SMC technical baseline.

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

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

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

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

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

(10) The definition of certification criteria for Operational Safety, Suitability, and Effectiveness (OSS&E) and Space Flight Worthiness (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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Appendix B — Acronyms

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

AFMC	Air Force Material Command
ANSI	American National Standards Institute
APB	Acquisition Program Baseline
ASR	Alternative Systems Review
C/SCS	Cost/Schedule Control System
C/SSR	Cost/Schedule Summary Report
C4I	Command, Control, Communications, Computers, and Intelligence
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance
CAIV	Cost As an Independent Variable
CARD	Cost Analysis Requirements Description
CCPD	Combat Capability Production Document (also written C-CPD)
CDD	Capability Development Document
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CFE	Contractor Furnished Equipment
CI	Configuration Item
CJCS	Chairman of the Joint Chiefs of Staff
CLIN	Contract Line Item Number
CONOPS	Concept of Operations
COTS	Commercial Off The Shelf
CPD	Capability Production Document
CPI	Critical Program Information
CRD	Capstone Requirements Document
CSCI	Computer Software Configuration Item
CSOW	Contract Statement of Work
CSU	Computer Software Unit
CWBS	Contract Work Breakdown Structure
DIA	Defense Intelligence Agency
DID	Data Item Description
DOD	Department of Defense
DODAF	DOD Architecture Framework
DOTMLPF	Doctrine, Organization, Training, Materiel, Leadership and education, Personnel and Facilities
EA	Evolutionary Acquisition
ECP	Engineering Change Proposal
EDMs	Engineering Development Models
EIA	Electronic Industries Alliance

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ESOH	Environmental Safety and Occupational Health
EVMS	Earned Value Management System
FCA	Functional Configuration Audit
FMECA	Failure Mode Effects and Criticality Analysis
FoS	Family of Systems
FOT&E	Follow-on Operational Test and Evaluation
FQR	Formal Qualification Review
FRACAS	Failure Reporting Analysis, Corrective Action System
FRD	Functional Requirements Document
FRP	Full Rate Production
GFE	Government Furnished Equipment
GFI	Government Furnished Information
GFM	Government Furnished Materiel
GFP	Government Furnished Property
HSI	Human Systems Integration
HWCI	Hardware Configuration Item
HWU	Hardware Unit
ICA	Independent Cost Assessment
ICD	Initial Capability Document; Interface Control Document (or Drawing)
ICE	Independent Cost Estimate
ILSP	Integrated Logistics Support Plan
IMP	Integrated Master Plan
IMS	Integrated Master Schedule
IAW	In Accordance With
IOC	Initial Operational Capability
IOT&E	Initial Operational Test and Evaluation
IPA	Integrated Program Assessment
IPAT	Integrated Program Assessment Team
IPD	Integrated Product Development
IPPD	Integrated Product and Process Development
IPT	Integrated Product Team
IRS	Interface Requirements Specification
I&T	Integration and Test
JCIDS	Joint Capabilities Integration and Development System
JTA	Joint Technical Architecture
KDP	Key Decision Point
KPP	Key Performance Parameter
LCC	Life Cycle Cost
LMU	Logistics Management Information
LOE	Level Of Effort
MIL-HDBK	Military Handbook
MIL-SPEC	Military Specification
MIL-STD	Military Standard
MMD	Mean Mission Duration

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MNS	Mission Need Statement
MOE	Measure Of Effectiveness
MOP	Measure of Performance
NDI	Non-Developmental Item
NEPA	National Environmental Policy Act
NSS	National Security System; National Security Space
O&S	Operations and Support
OA	Operational Architecture
ORD	Operational Requirements Document
OSA	Open System Architecture
OSS&E	Operational Safety, Suitability, and Effectiveness
OT&E	Operational Test and Evaluation
OV	Operational View
PCA	Physical Configuration Audit
PDR	Preliminary Design Review
PESHE	Programmatic Environmental, Safety, and Occupational Health Evaluation
PHS&T	Packaging, Handling, Storage and Transportation
PWBS	Program or Project Work Breakdown Structure
RFP	Request for Proposal
SDR	System Design Review
SE	Systems Engineering
SEMP	Systems Engineering Management Plan
SEP	Systems Engineering Plan
SFW	Space Flight Worthiness
SMC	Space and Missile Systems Center
SoS	System of Systems
SOW	Statement of Work
SPO	System Program Office
SRR	System Requirements Review
STAR	System Threat Assessment Report
STE	Special Test Equipment
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
TEMP	Test and Evaluation Master Plan
TOR	Technical Operating Report
TPM	Technical Performance Measure
TRD	Technical Requirements Document
TRL	Technology Readiness Level
TRR	Test Readiness Review

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TV	Technical View, Technical Standards View, or Technical Architecture View
UPC	Unit Production Cost
WBS	Work Breakdown Structure

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