Defense Acquisition Guidebook

Chapter 4 – Systems Engineering

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DEFENSE ACQUISITION GUIDEBOOK
Chapter 4 -- Systems Engineering

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4.0. Overview

4.0.1. Purpose

DAG Chapter 4 provides overarching guidance on the systems engineering (SE) discipline, its activities and processes, and its practice in defense acquisition programs. The Program Manager and the Systems Engineer should use DAG Chapter 4 to effectively plan and execute program activities across the system life cycle.

4.0.2. Contents

Section 4.1 Introduction defines Systems Engineering and why it is important.

Section 4.2 Systems Engineering Activities in the Life Cycle provides a by-phase description of key activities and the SE technical reviews and audits.

Section 4.3 Systems Engineering Processes provides a description of each process and contains the design considerations including specialty engineering.

4.1. Introduction

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Systems engineering (SE) establishes the technical framework for delivering materiel capabilities to the warfighter. SE provides the foundation upon which everything else is built and supports program success.

SE ensures the effective development and delivery of capability through the implementation of a balanced approach with respect to cost, schedule, performance, and risk using integrated, disciplined, and consistent SE activities and processes regardless of when a program enters the acquisition life cycle. SE also enables the development of engineered resilient systems that are trusted, assured, and easily modified (agile).

SE planning, as documented in the Systems Engineering Plan (SEP), identifies the most effective and efficient path to deliver a capability, from identifying user needs and concepts through delivery and sustainment. SE event-driven technical reviews and audits assess program maturity and determine the status of the technical risks associated with cost, schedule, and performance goals.

"Positive acquisition outcomes require the use of a knowledge-based approach to product development that demonstrates high levels of knowledge before significant commitments are made. In essence, knowledge supplants risk over time." (Source: GAO Report 12-400SP)

Additional SE benefits are it:

- Supports development of realistic and achievable program performance, schedule, and cost goals as documented in the Joint Capabilities Integration and Development System (JCIDS) documents, Acquisition Program Baseline (APB), Technology Development Strategy (TDS), and Acquisition Strategy (AS).
- Provides the end-to-end, integrated perspective of the technical activities and processes across the system life cycle, including how the system fits into a larger system of systems (SoS) construct.
- Emphasizes the use of integrated, consistent, and repeatable processes to reduce risk while maturing and managing the system baseline. The final product baseline forms the basis for production, sustainment, future changes, and upgrades.
- Provides insight into system life-cycle resource requirements and impacts on human health and the environment.

This chapter uses the following terms:

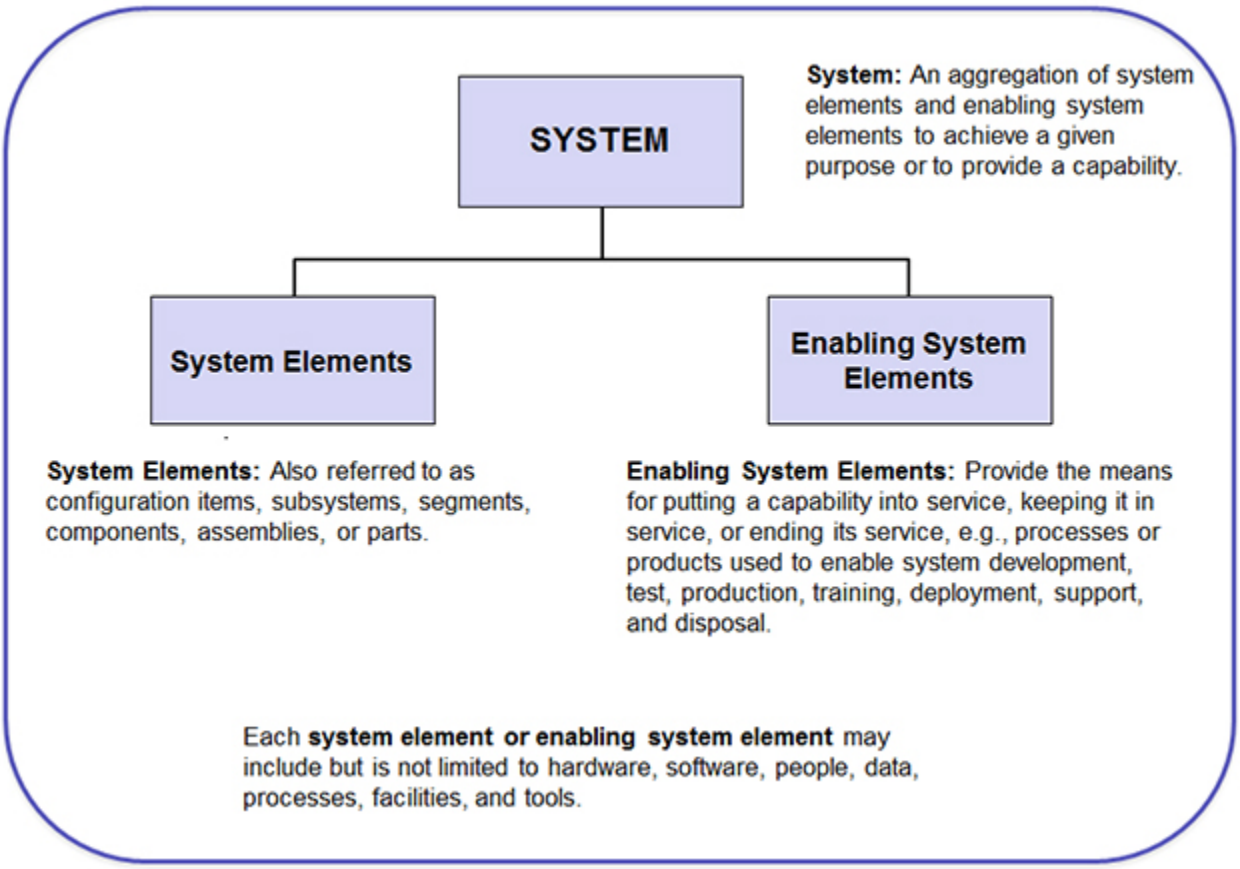
- The "Systems Engineer" refers to the Program Lead Systems Engineer, the Chief Engineer or Lead Engineer with SE responsibility, and the SE staff responsible for SE processes and who plan, conduct, and/or manage SE activities in the program.
- The "end user" includes the warfighter and other operational users, including support personnel, maintainers, and trainers who use or support the system.
- The "developer" refers to the system prime contractor (including associated subcontractors) or the Government agency responsible for designing and building the system.

Definition of Systems Engineering

Systems engineering (SE) is a methodical and disciplined approach for the specification, design, development, realization, technical management, operations, and retirement of a system. As

illustrated in Figure 4.1.F1., a system is an aggregation of system elements and enabling system elements to achieve a given purpose or provide a needed capability. The enabling system elements provide the means for delivering a capability into service, keeping it in service, or ending its service and may include those processes or products necessary for developing, producing, testing, deploying, and sustaining the system.

Figure 4.1.F1. The System



SE applies critical thinking to the acquisition of a capability. It is a holistic, integrative discipline, whereby the contributions across engineering disciplines such as structural engineers, electrical engineers, mechanical designers, software engineers, human factors engineers, and reliability engineers are evaluated and balanced to produce a coherent capability - the system.

The Systems Engineer balances the conflicting design constraints of cost, schedule, and performance while maintaining an acceptable level of risk. SE solves systems acquisition problems using a multi-disciplined approach. The Systems Engineer should possess the skills, instincts, and critical thinking ability to identify and focus efforts on the activities needed to enhance the overall system effectiveness, suitability, survivability and sustainability.

SE activities begin before a program is officially established and are applied throughout the

acquisition life cycle. Any effective SE approach should support and be integrated with sound program management. Prior to program initiation, the Program Manager, or Service lead if no Program Manager has been assigned, should perform development planning to lay the technical foundation for successful acquisition. Development planning encompasses the engineering analyses and technical planning activities that provide the foundation for informed investment decisions on which path a materiel development decision takes. Development planning effectively addresses the capability gap(s), desired operational attributes, and associated dependencies of the desired capability. In addition, development planning ensures that there exists a range of technically feasible solutions generated from across the entire solution space and that consideration has been given to near-term opportunities to provide a more rapid interim response to the capability need. Development planning is initiated prior to the Materiel Development Decision review, continues throughout the Materiel Solution Analysis phase, and transitions the knowledge (documents, tools, and related data) to the designated program.

Affordability

The Systems Engineer contributes to defining, establishing, and achieving affordability targets throughout the life cycle of the system. Affordability targets are based on what the Department can afford to spend for the capability, including program acquisition and sustainment costs. Affordability targets are used as design constraints in the development, procurement, and sustainment of an affordable system. See DAG section 4.3.18.2. Affordability - Systems Engineering Trade-Off Analyses, for more information on how affordability drives design decisions.

The Program Manager controls requirements growth and should use affordability goals early to guide design trades and program decisions. The Systems Engineer assists in managing affordability by working closely with the program cost estimator/analyst team when developing common cost and technical models and aligning baselines. See DAG Chapter 3 Affordability and Life-Cycle Resource Estimates for more information on affordability.

Throughout the acquisition life cycle, the Program Manager and Systems Engineer should monitor the system affordability, seek out cost saving opportunities, and identify any associated cost, schedule, and performance risks. The Program Manager's emphasis prior to Milestone B should be on defining and achieving affordability targets and desired capabilities. During the Technology Development (TD) phase, the Program Manager and Systems Engineer work to reduce technical risk and develop a sufficient understanding of the materiel solution development to validate design approaches and cost estimates, to refine requirements and to ensure affordability is designed in to the desired capability. After Milestone B, the emphasis shifts to defining and achieving should cost estimates.

Should cost management is a deliberate strategy to drive cost efficiencies and productivity growth into programs. The will cost estimate is the likely life-cycle cost of the system based on historical data and represents the program's independent cost estimate, i.e., as generated by the Cost Assessment and Program Evaluation (CAPE) office or Service equivalent. As the program identifies inefficiencies, the should cost estimate is developed based on specific actions and opportunities to mitigate, eliminate, or reduce those inefficiencies that allow the program to

come in below the expected will cost estimates. The Program Manager, with support from the Systems Engineer, develops program office cost estimates reflecting should cost opportunities and plans. The Program Manager uses the should cost estimate as a tool to:

- Influence design trades and choices when analyzing and setting contract/production execution targets
- Manage all costs throughout the product's life cycle
- Manage the product's final unit and sustainment cost
- Provide incentives for both of the parties (Government and industry) to execute efficiently: Government managers, who seek more value for the warfighter and taxpayer; and industry managers, who develop, build and sustain the systems and provide needed services

Should cost focuses on controlling the cost of both current and planned work. To have an impact, these activities should inform contract negotiations leading up to Engineering and Manufacturing Development (EMD) and Production and Deployment (P&D) phases. Should cost management does not mean trading away the long-term value of sound design practices and disciplined SE activities for short-term gain; it does mean eliminating non-value-added activities and reports that are not required and that are deemed unessential. For guidance on implementing should cost management, see the Better Buying Power website.

Program Managers address affordability requirements and begin to apply should cost management early in the acquisition life cycle. This includes applying SE to define an affordable system design while also working to eliminate inefficiencies and duplication where applicable and to drive productivity improvements into their programs.

Systems Engineering Processes

The practice of systems engineering (SE) is composed of 16 processes: eight technical processes and eight technical management processes as listed in Figure 4.1.F2. and described in DAG section 4.3. Systems Engineering Processes. These 16 processes provide a structured approach to increasing the technical maturity of a system and increasing the likelihood that the capability being developed balances mission performance with cost, schedule, risk, and design constraints.

The eight technical management processes are implemented across the acquisition life cycle and provide insight and control to assist the Program Manager and Systems Engineer to meet performance, schedule, and cost goals. The eight technical processes closely align with the acquisition life-cycle phases and include the top-down design processes and bottom-up realization processes that support transformation of operational needs into operational capabilities.

The ultimate purpose of the SE processes is to provide a framework that allows the SE team to efficiently and effectively deliver a capability to satisfy a validated operational need. To fulfill that purpose, a program implements the SE technical processes in an integrated and overlapping manner to support the iterative maturation of the system solution. The level of SE required supporting these processes declines as a program progresses into the later phases of the

acquisition life cycle. Implementation of the SE processes begins with the identification of a validated operational need as shown in the top left corner of the V-diagram (see Figure 4.1.F2). The technical processes enable the SE team to ensure that the delivered capability accurately reflects the operational needs of the stakeholders. The key activities that are accomplished by the execution of the technical processes are described below:

- During the Stakeholder Requirements Definition process, the operational requirements and inputs from relevant stakeholders are translated into a set of top level technical requirements. These requirements are decomposed and elaborated during the Requirements Analysis process to produce a complete set of system functional and performance requirements. (**Note:** Figure 4.1.F2 is provided as a framework to illustrate where requirements are addressed within the SE Process flow. See DAG section 4.3.11. Requirements Analysis Process for more information on operational and system requirements.)
- During the Architecture Design process, the Systems Engineer, often through system modeling, trade-offs, and decision analyses, captures the functional requirements and interdependencies in the system architecture. Trade-offs and analyses are also used to mature and realize the design of the system and system elements during the Implementation process, generating the product baseline.
- During the Integration process, the program assembles the system elements together to provide the system for testing in the Verification process (developmental tests verifying the functional requirements) and Validation process (operational tests validating the system meets the operational need), resulting in a validated solution.
- During the Transition process, the program formally delivers the system capability to the end users, including all enabling system elements to support operational use and sustainment activities.

The technical management processes, listed at the bottom of Figure 4.1.F2, provide a consistent approach to managing the program's technical activities and controlling information and events that are critical to the success of the program. Taken together, these 16 processes are a systematic approach focused on providing operational capability to the warfighter while reducing technical and programmatic risk.

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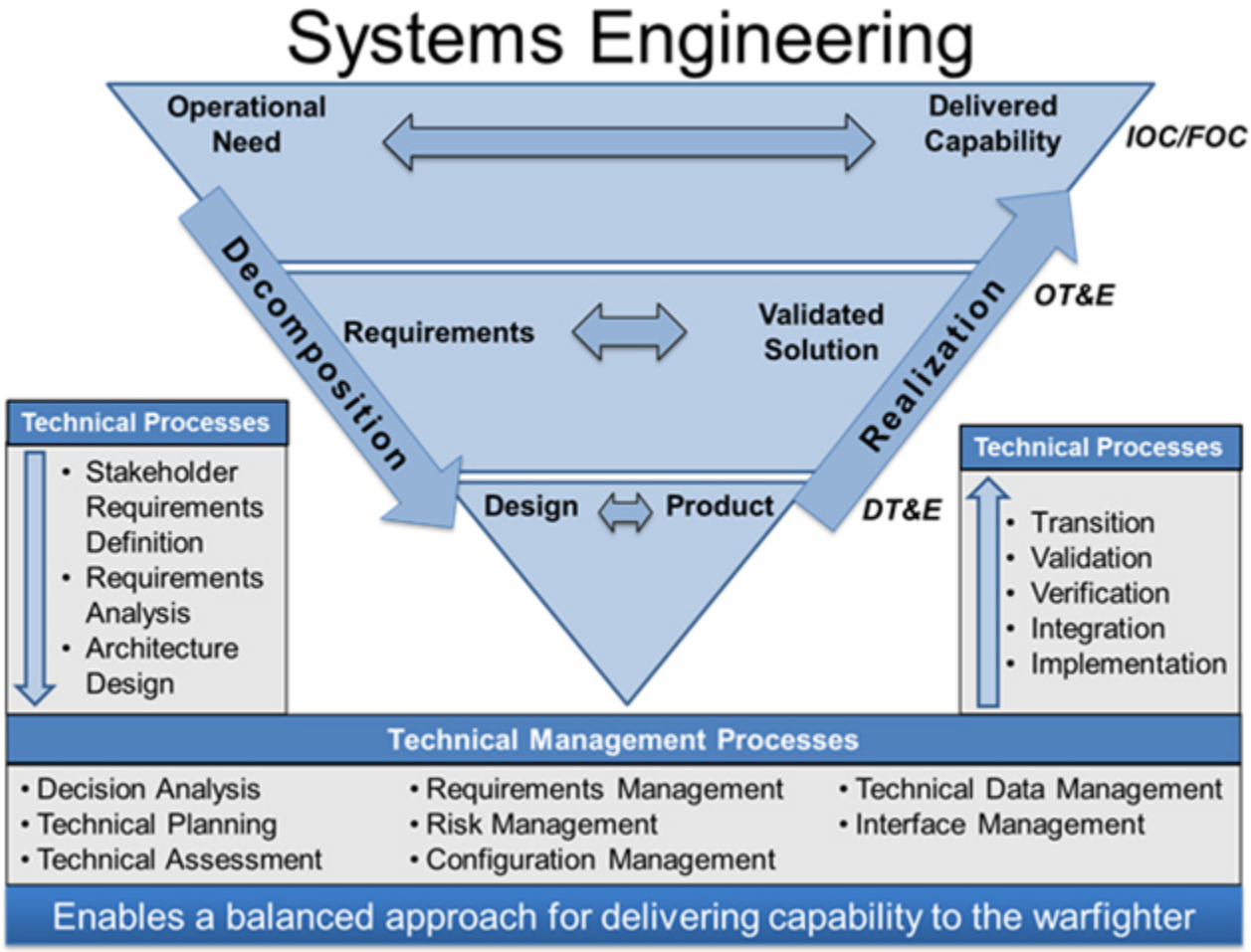
Figure 4.1.F2. Systems Engineering Processes



All organizations performing SE should scale their application and use of the processes in DAG section 4.3. Systems Engineering Processes to reflect the unique needs of the program and the type of product or system being developed. This scaling should reflect the system's maturity and complexity, size and scope, life-cycle phase, and other relevant considerations. For example, lower-risk, less-complex programs may scale the processes to ensure key activities are effective but not overly cumbersome (e.g., simpler and less-expensive tools, less-frequent reporting, and activities adjusted to fit smaller organizations with fewer personnel).

4.1.1. Systems Engineering Policy and Guidance

4.1.1. Systems Engineering Policy and Guidance

Policy and guidance related to systems engineering (SE) are intended to minimize the burden and cost on programs while maintaining technical integrity through the planning and execution of SE activities across the acquisition life cycle. Program Managers and Systems Engineers should know and understand the statutory and regulatory SE mandates. Table 4.1.1.T1 identifies top-

level SE-related policy and guidance.

Table 4.1.1.T1. Systems Engineering-Related Policy and Guidance

SE Policy and Guidance
DoDD 5000.01, The Defense Acquisition System
DoDI 5000.02, Operation of the Defense Acquisition System
DoDI 5134.16, Deputy Assistant Secretary of Defense for Systems Engineering (DASD(SE))
PDUSD(AT&L) Memorandum, "Improving Milestone Process Effectiveness"
PDUSD(AT&L) Memorandum, "Expected Business Practice: Post-Critical Design Review Reports and Assessments"
PDUSD(AT&L) Memorandum, "Document Streamlining - Program Strategies and Systems Engineering Plan"
PDUSD(AT&L) Memorandum, "Document Streamlining - Program Protection Plan (PPP)"
PDUSD(AT&L) Memorandum, "Document Streamlining - Life-Cycle Sustainment Plan (LCSP)"
USD(AT&L) Memorandum, "Implementation of Will-Cost and Should-Cost Management"
USD(AT&L) Memorandum, "Better Buying Power: Mandate for Restoring Affordability and Productivity in Defense Spending"
Additional SE-related guidance is provided on the Deputy Assistant Secretary of Defense for Systems Engineering (DASD (SE)) website

SE-related policy, guidance, specifications, and standards are intended to successfully guide the technical planning and execution of a program across the acquisition life cycle. Understanding the use and value of SE specifications and standards is fundamental to establishing, executing, and maintaining disciplined SE processes. The ASSIST document database is the official source for current DoD specifications and standards.

Compliance with mandated DoD SE policy is required for program approval and completion of successful milestone decisions. DoD policy and guidance provide a framework for structuring the program and help define the areas available for tailoring to effectively and efficiently deliver capability to the warfighter.

Within this policy and guidance framework, tailoring the acquisition effort to meet program cost, schedule, and performance goals is not only desired but mandated in accordance with DoDD 5000.01. In July 2012, USD(AT&L) emphasized there is no one-size-fits-all optimal program structure. Every program has its own optimal structure, and that structure is dependent on many variables that contribute to program success or failure. Areas that should be considered for tailoring include:

- The documentation of program information
- The execution of the acquisition phases
- The timing and scope of decision review
- The decision levels chosen to fit the particular conditions of the program in accordance with applicable laws and regulations
- The time-sensitivity of the capability need

The requirements of DoD SE policy that are identified for tailoring by the Program Manager are submitted to the Milestone Decision Authority (MDA) for approval.

The structuring of every program should start with a deep understanding of the nature of the capability intended to be acquired and the effort needed to realize that capability. Critical thinking during early program formulation is important to clearly identify the internal and external stakeholders, system interdependencies, technological opportunities, contractual and budgetary constraints, and policy mandates. The optimal program structure includes the set of technical activities, events, and management mechanisms that best address the unique circumstances and risks of the program.

All program strategy and planning documents depend on SE activities to define and balance requirements against cost, schedule, and risks; identify potential solutions; assess the maturity and feasibility of available technologies; develop a realistic schedule; and allow for multiple other considerations affecting the final cost and delivery of capability to the warfighter. Therefore, the Program Manager should build a program office structure that ensures the Systems Engineer is an integrated part of the program planning and execution activities.

The Systems Engineer leads or is a key enabler in the planning and execution of the program's technical approach. To aid this planning, the Systems Engineer should proactively seek experience from similar past and current programs and map this learning as applicable into the SE planning of the program (see also DAG section 4.3.19.4. Lessons Learned, Best Practices, Case Studies).

4.1.2. Systems Engineering Plan

4.1.2. Systems Engineering Plan

The purpose of the Systems Engineering Plan (SEP) is to help Program Managers develop, communicate, and manage the overall systems engineering (SE) approach that guides all technical activities of the program. The SEP documents key technical risks, processes, resources, metrics, SE products, and completed and scheduled SE activities. The SEP is a living document that should be updated as needed to reflect the program's evolving SE approach and/or plans and current status. The PDUSD(AT&L) memorandum, "Program Strategies and Systems Engineering Plan" requires programs to use the SEP Outline to guide SEP preparation. The SEP Outline identifies the minimum expected content to be addressed in the SEP. The SEP should be consistent with and complementary to the Acquisition Program Baseline (APB), Technology Development Strategy (TDS), Acquisition Strategy (AS), Test and Evaluation Strategy (TES), Test and Evaluation Master Plan (TEMP), Program Protection Plan (PPP), Life-Cycle Sustainment Plan (LCSP), and other program plans as appropriate. The SEP should be written in a common language to clearly communicate what the program plans to do in each phase of the acquisition life cycle and should be written to avoid redundancy and maintain consistency with other planning documents.

For Major Defense Acquisition Programs (MDAPs), the Program Manager should formally charter a SE Working-Level Integrated Product Team (WIPT), led by the Systems Engineer, to

assist in developing and monitoring SE activities as documented in the program SEP. DoDI 5000.02, Public Law 111-23 (Weapon Systems Acquisition Reform Act), and DoDI 5134.16 require a formal SEP to be approved by the Deputy Assistant Secretary of Defense for Systems Engineering (DASD(SE)) for all Acquisition Category level 1 (ACAT I) and potential ACAT I programs prior to Milestones A, B, and C and program restructures. The PDUSD(AT&L) memo on "Improving Milestone Process Effectiveness" requires that a draft formal SEP be available for the pre-Engineering and Manufacturing Development (pre-EMD) review. For all lower ACAT programs, the Component Acquisition Executive or delegated authority approves the SEP. As a best practice, SEP updates should be approved by the Program Executive Office (PEO) prior to each technical review and when the program changes in a way that has an impact on the technical strategy. The Program Manager may approve other periodic updates to the SEP.

The SEP describes the integration of SE activities with other program management and control efforts, including the Integrated Master Plan (IMP), Work Breakdown Structure (WBS), Integrated Master Schedule (IMS), Risk Management Plan (RMP), Technical Performance Measures (TPMs), and other documentation fundamental to successful program execution. The SEP also describes the program's technical requirements, engineering resources and management, and technical activities and products as well as the planning, timing, conduct, and success criteria of event-driven SE technical reviews throughout the acquisition life cycle. As a best practice, the Government SEP should accompany the Request for Proposal (RFP) as guidance to the offerors. The developer's Systems Engineering Management Plan (SEMP), which is the contractor-developed plan for the conduct, management, and control of the integrated engineering effort, should be consistent with the Government SEP to ensure that Government and contractor technical plans are aligned. The SEMP should define the contractor technical planning and how it is accomplished from the contractor perspective, and articulates details of their processes, tools, and organization.

As the program's blueprint for the conduct, management, and control of all technical activities, the SEP captures decisions made during the technical planning process and communicates objectives and guidance to program personnel and other stakeholders. The SEP should define the "who, what, when, why, and how" of the SE approach, for example:

- The program organization with roles and responsibilities, authority, accountability, and staffing resources. This includes the coordination of the program's integrated product teams (IPTs) and their products, resources, staffing, management metrics, and integration mechanisms.
- The key activities, resources, tools, and events that support execution of the SE technical processes and technical management processes (see DAG section 4.3. Systems Engineering Processes) to deliver a balanced solution to meet the warfighter's needs. It should identify unique processes, tools, and/or tailoring of organizational and Government standards, how these processes and tools are integrated, and how products are developed and managed.
- The event-driven technical review approach based on successful completion of key activities as opposed to calendar-based deadlines. The SEP should identify the timing of SE events in relation to other program events and key knowledge points, and it should describe how technical activities are integrated in the program's overall plan and

schedule. The SEP should include the assumptions made in developing the schedule and the process for conducting schedule risk assessments and updates.

- The approach for how requirements and technical performance trade-offs are balanced within the larger program scope to deliver operationally effective, suitable, and affordable systems. Key design considerations and criteria (see DAG section 4.3.18. Design Considerations) should be listed in the mandatory table as applicable, with the associated plans embedded in the SEP or hot linked so that responsible staff can monitor system compliance.
- The SE tools and other enablers integrated and used to support SE processes, technical design initiatives, and activities.

4.1.3. Systems Level Considerations

4.1.3. Systems Level Considerations

A system should not be acquired in isolation from other systems with which it associates in the operational environment. The Program Manager and Systems Engineer should understand how their system fills the needs for which it was designed and the enterprise context within which it operates. This includes understanding the diverse or dissimilar mix of other systems (hardware, software, and human) with which the system needs to exchange information. To that end, the Program Manager and Systems Engineer should define intersystem interfaces using a systems engineering (SE) document, i.e., the interface control document(s). In addition to interface control documents, the Program Manager and Systems Engineer, should also actively pursue Memoranda of Agreement or Memoranda of Understanding (MOA/MOU) with companion programs regarding interfaces, data exchanges, and advance notices of changes interdependencies and schedule (timing) that may affect either program. These agreements are a professional courtesy and a means of mitigating the inherent risk in planning to deliver a capability to an anticipated future technical baseline when there is uncertainty that the other programs are able to maintain schedule and have adequate resources to deploy the capabilities as planned.

SE is increasingly recognized as key to addressing the evolution of complex systems of systems. SE principles and tools can be used to apply systems thinking and engineering to the enterprise levels. An enterprise in this usage is understood to be the organization or cross-organizational entity supporting a defined business scope and mission, and includes the interdependent resources (people, organizations, and technology) to coordinate functions and share information in support of a common mission or set of related missions, (reference "Federal Enterprise Architecture Framework (FEAF)," September 1999).

This application of SE to address enterprises as complex systems builds on traditional SE activities and expands them to address enterprise challenges. The Systems Engineer can also assist with enterprise strategic planning and enterprise investment analysis. These two additional roles for Systems Engineers at the enterprise level are "shared with the organization’s senior line management, and tend to be more entrepreneurial, business-driven, and economic in nature in comparison to the more technical nature of classical systems engineering," (reference Charlock, P.G., and R.E. Fenton, "System-of-Systems (SoS) Enterprise Systems for Information-Intensive

Organizations," Systems Engineering, Vol. 4, No. 4 (2001), pages 242-261).

Each DoD Service and Agency, and the Department itself, are examples of enterprises as systems. Such organizations have the challenge of integrating and evolving multiple portfolios of systems often with conflicting sets of objectives, constraints, stakeholders, and demands for resources.

The Systems Engineer should be cognizant of the enterprise context and constraints for the system in development and should factor these enterprise considerations into acquisition technical decisions from the outset. Mission areas, for example, can be viewed as cross-organizational enterprises and also provide critical context for system acquisition. Controlled interfaces with enabling systems in the SoS architecture drive system design. In some cases, enterprise considerations have been articulated as standards and certification requirements. In other cases, system decisions need to be made in the context of the larger Service portfolio of systems and mission area needs.

Most DoD capabilities today are provided by an aggregation of systems often referred to as systems of systems (SoS). A SoS is described as a set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities. For complex SoS, the interdependencies that exist or are developed between and/or among the individual systems being integrated are significantly important and need to be tracked. Each SoS may consist of varying technologies that matured decades apart, designed for different purposes but now used to meet new objectives that may not have been defined at the time the systems were fielded.

Both individual systems and SoS conform to the accepted definition of a system in that each consists of parts, relationships, and a whole that is greater than the sum of its parts; however, not all systems are SoS. There are distinct differences between systems and SoS that should be taken into account in the application of SE to SoS (see Table 4.1.3.T1, adapted from DoD Systems Engineering Guide for Systems of Systems, page 11).

Table 4.1.3.T1. Comparing Systems and Systems of Systems

	System	System of Systems (SoS)
Management & Oversight		
Stakeholder Involvement	Clearer set of stakeholders	Two levels of stakeholders with mixed, possibly competing interests. The two levels of stakeholders represent: 1. the independent and useful systems 2. the aggregation of the independent and useful systems
Governance	Aligned PM and funding. Higher levels of governance such as PEO and AT&L (internal and external governance)	Added levels of complexity due to management and funding for both SoS and systems; No single manager controls all constituent systems in the SoS

	System	System of Systems (SoS)
Operational Environment		
Operational Focus	Designed and developed to meet operational objectives	Called upon to provide integrated capabilities using systems whose objectives have not been directly derived from current SoS system's objectives
Implementation		
Acquisition	Aligned to established acquisition process	Multiple system life cycles across acquisition programs, involving legacy systems, systems under development, new developments, and technology insertion; Stated capability objectives but may not have formal requirements
Test & Evaluation	Test and evaluation of the system is possible	Testing more challenging due to system's asynchronous life cycles and given the complexity of all the moving parts
Engineering & Design Considerations		
Boundaries & Interfaces	Focuses on boundaries and interfaces	Focus on identifying systems contributing to SoS objectives and enabling flow of data, control, and functionality across and/or between the SoS while balancing needs of systems. The boundaries and interfaces between systems become very important, since they serve as a conduit for data transfer
Performance & Behavior	Ability of the system to meet performance objectives	Performance across the SoS that satisfies SoS user capability needs while balancing needs of the systems

Application of Systems Engineering to Systems of Systems

Systems of systems (SoS) systems engineering (SE) deals with planning, analyzing, organizing, and integrating the capabilities of new and existing systems into a SoS capability greater than the sum of the capabilities of its constituent parts. Consistent with the DoD transformation vision and enabling net-centric operations, SoS may deliver capabilities by combining multiple collaborative and independent-yet-interacting systems. The mix of systems may include existing, partially developed, and yet-to-be-designed independent systems.

The DoD Guide to Systems Engineering for Systems of Systems addresses the application of SE to SoS. The guide defines four types of SoS (see Table 4.1.3.T2). When a SoS is recognized as a "directed," "acknowledged," or "collaborative" SoS, SE is applied across the constituent systems and is tailored to the characteristics and context of the SoS. Due to increased efforts to network systems to facilitate information sharing across the battlespace, most DoD systems also may be viewed as components of a "virtual" SoS. For virtual SoS, DoD net-centric policies and strategies, such as, Department of Defense Net-Centric Services Strategy provide SE guidance regarding SoS contexts where there is an absence of explicit shared objectives or central management.

Table 4.1.3.T2. Four Types of Systems of Systems

Type	Definition
Directed	Directed SoS are those in which the SoS is engineered and managed to fulfill specific purposes. It is centrally managed during long-term operation to continue to fulfill those purposes as well as any new ones the system owners might wish to address. The component systems maintain an ability to operate independently, but their normal operational mode is subordinated to the centrally managed purpose.
Acknowledged	Acknowledged SoS have recognized objectives, a designated manager, and resources for the SoS; however, the constituent systems retain their independent ownership, objectives, funding, development, and sustainment approaches. Changes in the systems are based on cooperative agreements between the SoS and the system.
Collaborative	In collaborative SoS, the component systems interact more or less voluntarily to fulfill agreed-upon central purposes.
Virtual	Virtual SoS lacks a central management authority and a centrally agreed-upon purpose for the system of systems. Large-scale behavior emerges-and may be desirable-but this type of SoS relies upon relatively invisible, self-organizing mechanisms to maintain it.

4.1.3.1. Software

4.1.3.1. Software

Software is a key enabler for almost every system, making possible the achievement and sustainment of advanced warfighting capabilities. Development and sustainment of software is frequently the major portion of the total system life-cycle cost, and factors such as safety, security, reliability, interoperability, and insertion of new technology are considered at every decision point in the acquisition life cycle.

Software engineering requires unique technical management and contracting expertise to address architectures, requirements mapping, integration, technical data rights, assurance, and suitability for intended use. The more critical or complex the software acquisition effort, the more important it is to seek developers with demonstrated experience and knowledge (for more information on the uses of external resources see DAG section 4.1.4. Engineering Resources). The Program Manager should understand software development principles and best practices. To support program protection, program planning, contracting, configuration management, integration, test, and sustainment, the Program Manager should also have a working knowledge of software terms, tools, development models, risks, and challenges. These elements are major cost drivers for software in complex systems. Because key system capabilities are now more frequently implemented in software, techniques that estimate and assess function size, cost, performance, and risk are required for program planning, contract development, and progress assessment. Systems engineering (SE) principles and practices help anticipate, plan for, and

mitigate challenges and risks in software development and system integration.

Establish the software acquisition strategy as early as possible to address function and component allocation to software and determine what is to be developed, what is provided as Government off-the-shelf (GOTS) software, commercial-off-the-shelf (COTS) software, or open source software (OSS), and what is a mix or hybrid. The strategy also incorporates plans for associated data and intellectual property rights for GOTS, COTS, and OSS.

Software-intensive acquisitions typically involve modeling and simulation (M&S) in engineering support roles specific to each phase of acquisition. Example uses of M&S in software acquisition are to:

- Study development cost by function,
- Study feasibility of the prospective system in the intended operational environment,
- Conduct engineering trade-offs and analyses of alternatives,
- Study and refine viability of planned software and computers to meet KPPs,
- Simulate undeveloped equipment during software testing, and
- Emulate the interoperability environment of the system during integration.

M&S activities are most valuable earlier in program planning as decision support tools and may be used iteratively to assess evolving functional architectures. The cost of M&S is allocated during initial program planning. Cost basis is the rationale supporting the balance between M&S cost and degree of needed risk reduction. M&S used by a Program Manager to make decisions should be verified and validated to the intended use in a time frame before assessment is needed. Data used by M&S to support assessments should have a known pedigree and should be adequate to the level of assessment. See DAG section 4.3.19.1. Modeling and Simulation for more information.

An incremental software development approach enables the developers to deliver capability in a series of manageable releases or builds to gain user acceptance and feedback for the next increment and reduce the overall level of risk. Frequent requirements and design-validation activities involving the end users and developers can assist the program to define viable increments of capabilities that have operational value for early fielding before the whole system capability is delivered. This incremental approach may not be viable when the end system is not usable until the entire set of essential capabilities is integrated and tested. For example, weapon systems are dependent upon software for real-time controls that can affect life and safety. As such, these weapon systems are required to be qualified and certified for security, safety, and interoperability before being released for operational use. In addition, safety and security assurance certifications and approvals require a predetermined objective level of rigor in verification, validation, and accreditation (VV&A) of these software releases. This VV&A is based on risk, not on the complexity, number of software lines of code (SLOC), or size of each software release. The Joint Software Systems Safety Handbook provides guidance for implementing safety-critical software designs with the reasonable assurance that the software executes within the system context and is at an acceptable level of safety risk.

Iterative development approaches should be planned well in advance and should consider

impacts to other system elements of the functional architecture or other interconnecting systems. The program should focus on the allocation of functional architecture elements to the physical architecture and identifying the interdependencies and associated technical risks as part of determining the content for each iteration or build. Incremental or iterative development should be employed to carefully define the final end state of the supporting physical hardware elements when functionality or capability is to be added over time. Memory, processor overhead, and input/output capacity should be designed to support growth in capability. Implementing an open systems architecture (OSA) as part of the software design and development increases design flexibility, supports incremental deliveries, allows for opportunities to use COTS and OSS, facilitates future upgrades and modifications, and supports technology insertion (see DAG sections 4.3.18.4. Commercial-Off-the-Shelf and 4.3.18.15. Open Systems Architecture).

Software SE uses architectural modeling to develop and refine software requirements and to partition a system's software into components and subcomponents. Software architectural decisions are driven by principles including co-location of external interfaces in one component to reduce risk of vulnerability, aggregating functions having higher mutual interaction, determining components that have well-defined interfaces to other components as candidates for technology insertion or OSS in support of OSA, and allocation of functionality to maximize use of COTS given acceptable risk.

When employing COTS software, criteria for selecting among competitive alternatives may not include details of commercial design or performance but should require ample evidence that the software is adequate for its intended use. Code-scanning tools should be used to help ensure that COTS software does not pose a security or software assurance risk. (See DAG Chapter 7 Acquiring Information Technology, Including National Security Systems and NIST-SP-800 series publications for additional information.) In addition, mitigation of security and information assurance risks associated with COTS software go beyond code-scanning techniques for their solution. Those risk mitigation efforts should be expanded to make use of activities identified in DAG section 4.3.18.24. System Security Engineering, as well as the activities discussed in DAG Chapter 13 Program Protection.

In programs for which software capability is procured as a service, the service-level agreement(s) (SLA) should reflect operational or field performance including all path constraints, such as satellite time delays, low data rate access, and intermittent service, as part of the operational environmental constraints and potential security requirements. These SLA provisions are important because service providers may not be willing to disclose details of their operations and staffing (such as overseas data centers or help desks).

It is not uncommon for weapon system acquisitions to contain a mix of Government-off-the-shelf (GOTS) software with complete technical data and software rights, other software items with restricted Government purpose rights, and software with virtually no rights other than the commercial license to use or access the software (see FAR Subpart 27.4). The Systems Engineer and Program Manager should be aware of the implications of these differences regarding acquisition and sustainment costs, performance, and the consequences on change control and sustainment of deployed systems. For deployed systems, the Systems Engineer should understand the system concept of operations (CONOPS), any maintenance plans, the targeted

audience that is expected to use the software application, and level of training of the potential users. This understanding is necessary in order to effectively balance the cost, scheduling and potential risks in maintenance, training, and documentation.

As a best practice, the Systems Engineer for a software-intensive system, defined as "a system in which software represents the largest segment in one or more of the following criteria: system development cost, system development risk, system functionality, or development time" (DAU Glossary of Acronyms and Terms), should be well versed in the technical and management activities of computer programming, software project planning, and software configuration management, including defining computer software configuration items. The SE approach should include software engineers early in the acquisition life cycle to ensure software considerations are included in defining and allocating software-related requirements and generating cost and schedule estimates, especially for software-intensive systems. Software engineers are also needed to evaluate the developer's software architecture, functional baseline, allocated baseline, and product baseline, documents, plans, and estimates, including M&S capabilities and facilities. Program-independent software engineers should support validation activities.

SE processes should be adapted to address considerations of hardware, software, and human systems integration. For example, risk management activities for hardware, software, and human systems integration should be combined so that risk mitigation plans can address all hardware, software, and human systems integration aspects of individual risks.

For software-related acquisitions the Systems Engineering Plan (SEP) should consider the following, as a minimum, for software SE planning:

- Software-unique risks
- Inclusion of software in technical reviews, with the addition of the Software Specification Review (SSR) as a precursor to the Preliminary Design Review (PDR) for software-intensive systems
- Software organization, integrated product teams, and relationships to interdependent organizations
- Software technical performance, process, progress, and quality metrics (see DAG section 4.3.4. Technical Assessment Process)
- Software safety, security, protection, and similar requirements, including processes, architecture, and interfacing systems
- Configuration management, verification, and validation of software integration labs/facilities used as tools for software development
- Open systems architecture, associated data rights, and sustainment considerations
- Automated test plans, development tools, and pedigreed data to support modeling of requirements, design, and environmental interfaces
- Software problem reporting and assessment, code development, build generation, and regression testing
- Software independent verification and validation (IV&V) to be accomplished, especially as it relates to contractor proprietary software
- Versioning, data control, and testing, especially for GOTS

- Verification of documentation, configuration management, test relevancy, and other considerations for legacy versus new software

Each of the Services provides additional guidance to assist the Program Manager, Systems Engineer, and Software Engineers on software-intensive systems:

- The Department of the Navy published a Guidebook for Acquisition of Naval Software-Intensive Systems.
- The Department of the Air Force has published the Weapon Systems Software Management Guidebook.
- The Department of the Army provides software metrics recommendations within DA-PAM-70-3, Army Acquisition Procedures and DA-PAM-73-1, Test and Evaluation in Support of Systems Acquisition.

Software Integrated within the Acquisition Life Cycle

Software considerations occur and vary throughout the acquisition life cycle, with specific activities associated with each acquisition phase described in Table 4.1.3.1.T1.

Table 4.1.3.1.T1. Acquisition Phase-Specific Software Considerations

Phase	Software Considerations
Materiel Solution Analysis	Some system requirements map directly to software requirements, while others can be implemented in hardware or firmware, providing opportunities for trade-offs and studies that optimize design and reduce vulnerabilities and risks. The ability to analyze and model options, and articulate the pros and cons of each, can have long-range impacts on the delivered system, suitability for intended use, and ultimate life-cycle cost.
Technology Development	Competitive prototyping of software-intensive systems helps to identify and mitigate technical risks. System prototypes may be physical or math models and simulations that emulate expected performance. High-risk concepts may require scaled models to reduce uncertainty too difficult to resolve purely by mathematical emulation. On occasion, competitive full-scale prototypes are needed to resolve cost/benefit alternatives between competing software-intensive system designs. Software programs typically conduct a Software Specification Review (SSR) to assess the software requirements and interface specifications for computer software configuration items, in support of the Preliminary Design Review (PDR). The software trouble reporting system is in operation and may be used to track any remediation in design and software code and unit testing.

Phase	Software Considerations
Engineering and Manufacturing Development	To demonstrate that the detailed software design is complete at Critical Design Review (CDR), software documentation should represent the design, performance, and test requirements, along with the development and software/systems integration facilities to be employed in coding and integrating the deliverable software. Software and systems used for computer software configuration item development such as simulations and emulations, should be validated, verified, and ready to begin coding upon completion of the CDR, starting the implementation and synthesis of the software products. Software trouble reporting is used extensively to track problems and problem criticality levels. Problem report metadata should be selected so that the reports are relevant in development, test, and in operation to tracking and assessments. Typically, software functions vary in mission criticality so that problems reported in those functions are more critical to the system. There is legacy problem report tracking information that can be used to generally profile and predict which types of software functions may accrue what levels of problem reports. Program progress decisions can be made based on assessments of patterns of problem reports among software components of the system.
Production and Deployment	Software may be refined as needed in response to operational test and evaluation activities and in support of the Full-Rate Production and/or Full Deployment Decision and Initial Operational Capability.
Operations and Support	The In-Service Review (ISR) assesses user acceptance and potential upgrades on delivered software systems. A block change or follow-on incremental development may be defined that delivers maintenance, safety, or urgent builds and upgrades to the field in a controlled manner. Procedures for updating and maintaining software on fielded systems can require operators to download new builds or to install them from physical media, and may require more training. Procedures should be in place to support effective configuration management and control. There are inherent risks involved in modifying software on fielded systems upon which warfighters depend while engaged in frontline activities. Another aspect of the hardware-software interaction is that maliciously altered devices or inserted software can infect the supply chain, creating unexpected changes to systems. Vigilance is needed as part of supply chain risk management (see DAG Chapter 5 Life-Cycle Logistics and Chapter 13 Program Protection). Upon completion of development, the problem report tracking system can be used with other factors as legacy information to inform system and component upgrades. During Operations and Support phase, software problem reporting is continued.

Factors for Managing Software-Intensive Systems

Programs consider several factors when managing software-intensive systems, including the following:

Software Development Plan (SDP): The SDP as a best practice provides details below the level of the Systems Engineering Plan (SEP) and the contractor's Systems Engineering Management Plan (SEMP) for managing software development and integration. The SDP Data Item Description (DID) DI-IPSC-81427A is a tailorable template and a useful starting point in defining a software development plan. The SDP provides the Systems Engineer with insight into, and a tool for monitoring, the processes being followed by the developer for each activity, the

project schedules, the developer's software organization, and resource allocations.

Post-Deployment Software Support (PDSS): The management of the software development process and the implementation of a process that ensures software supportability are among two of the most difficult challenges facing the Program Manager in management of software-intensive systems. The Program Manager should effectively address the issues of software supportability, the software test environment, and other equipment, material, and documentation, including data rights that are required to provide PDSS for those end users identified in the SDP or in other documents similar to the Computer Resources Life Cycle Management Plan. (For more information on PDSS see MIL-HDBK-347.) Successful PDSS planning should assist the Program Manager in controlling software life-cycle costs.

Data Protection and Software Assurance: These factors are defined as the level of confidence that software functions as intended and is free of vulnerabilities, either intentionally or unintentionally designed or inserted as part of the software code, throughout the acquisition life cycle. The Program Manager is responsible for protecting system data and software, whether the data are stored and managed by the program office or by the developer (see DAG Chapter 13 Program Protection).

Software Data Management and Technical Data Rights: Rights associated with commercial products can be highly restrictive and are defined in licenses that may restrict the number of copies made and ability to alter the product. Often there is no assurance of suitability for intended purposes and no recourse to the vendor. Open source, sometimes referred to as "freeware," may not be free and may also have restrictions or carry embedded modules that are more restrictive than the overall package. The Program Manager, Systems Engineer, software engineer, and contracting officer should be familiar with the restrictions placed on each software item used in the contract or deliverable to the Government. The Program Office should determine the necessary intellectual property rights to computer software and should ensure that the intellectual property right should be determined in advance of the RFP and contract award and that they are acquired as needed, including:

- All requirements tools and data sets;
- All test software and supporting information necessary to build and execute the tests;
- All other software test tools such as interface simulators and test data analyzers whether custom-developed or not; and
- All information for defects remaining in the software upon delivery to the Government.

Software Reuse: The reuse of any system, hardware, firmware, or software should be addressed in multiple plans and processes throughout the acquisition life cycle, including the SEP, SDP, firmware development plan, configuration management plan, test plans (Test and Evaluation Master Plan, Software Test Plan, Independent Verification and Validation Plan), and quality assurance plans (system and software). (**Note:** Software reuse has traditionally been overestimated in the beginning of programs, and software reuse has often proven to be more costly than new software development. Software reuse plans should be monitored as a potential risk.) For more discussion of the reuse of software, see DAG section 4.3.18.15. Open Systems Architecture.

Software Acquisition and Sustainment Costs: Related costs should be accurately estimated in advance and then tracked to monitor execution within program cost constraints using relevant metrics (size, complexity, productivity factors, quality, development organization's past performance/productivity, etc.).

Government and Industry Teaming: Teaming is needed in order for the Government to successfully acquire software-reliant systems with industry as a partner. As a result of the teaming agreement, the Government may be able to use the experience and expertise of its industry partner. Extensive teaming with industry makes it incumbent on the Government to ensure that it maintains current and applicable software engineering expertise.

Software Safety: Software safety is applicable to most DoD systems as a factor of the ubiquitous nature of software-driven functions, network connectivity, and systems of systems (SoS). Specific mandatory certifications such as "air worthiness certification" require attention early in the development cycle to ensure adequate documentation and testing are planned and executed to meet certification criteria. Systems Engineers are encouraged to check with certification authorities frequently because rules can change during development.

4.1.4. Engineering Resources

4.1.4. Engineering Resources

Organizing and staffing the systems engineering (SE) organization and providing supporting resources and tools are critical tasks that merit attention from both the Program Manager and Systems Engineer because these tasks influence the effective implementation and control of the SE approach. The Program Manager is responsible for developing a tailored strategy that enables a cost-effective program to deliver a required capability within the needed delivery time. However, any program tailoring should be based on SE assessments of maturity and risk in order to determine the appropriate entry point into the acquisition life cycle and to identify opportunities to streamline the acquisition strategy. Therefore, the Program Manager should create a program office structure ensuring the Systems Engineer is an integrated part of the program planning and execution activities.

Building an integrated SE team with the expertise and knowledge to implement and execute an effective program is a key to success. The structure and size of the SE organization should reflect both the risk and complexity of the system under development and its life-cycle phase. The Systems Engineering Plan (SEP) describes the SE organizations of both the Government program office and, when available, the developer organization.

Roles and Responsibilities

To provide the required capabilities in the most efficient and effective manner, the Program Manager should ensure completion of the following activities that affect the technical approach:

- Ensuring proper level of governance is applied
- Ensuring processes are followed and reporting is in compliance with plans

- Interfacing with the end users and developers to determine changes in operational requirements or concepts of operations that may affect the development of the desired capability
- Ensuring coordinated development and updating of acquisition strategy documents (e.g., Technology Development Strategy (TDS) and Acquisition Strategy (AS)), program plans (e.g., SEP, Program Protection Plan (PPP), Test and Evaluation Master Plan (TEMP), and Life-Cycle Sustainment Plan (LCSP)), and cost and budget documents
- Establishing program office organization (roles, responsibilities, authorities accountabilities) and staffing the program office and Government technical team with qualified (trained and experienced) Systems Engineers and other relevant technical professionals
- Integrating all aspects of the program office, including business processes relating to program management, SE, test, and program control
- Ensuring all necessary memoranda of understanding and agreement (MOU/MOAs) are in place and sufficiently detailed
- Resourcing the managers of all functional areas such as administration, engineering, logistics, test, etc.
- Managing program risks by developing, resourcing, and implementing realistic mitigation strategies
- Approving the configuration management plan and ensuring adequate resources are allocated for implementing configuration management throughout the life cycle
- Reviewing/approving Engineering Change Proposal (ECP) requests and determining the path forward required by any baseline changes
- Ensuring contracting activities are coordinated with the program systems engineering team

The Systems Engineer is responsible for planning and overseeing all technical activity within the program office and for managing effective SE processes. The Systems Engineer should ensure the Program Manager has sufficient and clear information for scheduling and resource-allocation decisions. In addition, the Systems Engineer implements and controls the technical effort by:

- Implementing and maintaining disciplined SE processes
- Understanding the nature of the system under development, the needs of the end user, and the operating environment as described in the concept of operations
- Conducting activities in support of contract award and execution
- Ensuring that no constructive changes and unauthorized commitments are made with the contractor or developer
- Understanding how the system fits into a larger system of systems (SoS) context
- Providing recommendations on the contract strategy
- Assisting in generating affordability targets and should-cost goals by analyzing and verifying technical assumptions used in the cost analyses and related cost and budget documents
- Assessing process improvement activities in support of should-cost goals
- Developing and maintaining the SEP in coordination with key stakeholders and other functional experts who participate in the program development activities
- Tracking and managing the execution of the contract's SE-related tasks and activities in

each acquisition phase as detailed in the SEP
- Working closely with developer's SE teams to ensure integrated and effective processes
- Planning and executing the formal technical reviews and audits
- Tracking and reporting baseline changes and recommending a path forward, as a part of configuration management
- Supporting the Program Manager in configuration management activities
- Identifying and mitigating the program's technical risks which include
    - Integration risks
    - Engineering risks
    - Critical technology risks assessed in the Technology Readiness Assessment (TRA)
- Measuring and tracking program maturity using technical performance measures, requirements stability, and integrated schedules
- Updating the PPP
- Staffing the engineering team with qualified and appropriate engineers
- Supporting updates to the TEMP and LCSP
- Supporting test and evaluation activities as documented in the TEMP (see Chief Developmental Tester responsibilities in DAG Chapter 9 Test and Evaluation)
- Reviewing requirements traceability matrix and cross reference matrix (verification)
- Managing root cause and corrective action (RCCA) efforts along with supporting the risk boards
- Ensuring selection of qualified vendors for parts, materiel, and processes (for hardware and software)
- Reviewing deliverables on the contract to ensure compliance and utility, and to ensure appropriate format and content

One of the key responsibilities of the Systems Engineer is to provide insight/oversight of the technical activities of the capability acquisition. To ensure the success of integrated processes the Systems Engineer should maintain continuous engagement with the developer's Systems Engineer responsible to build, deploy, and sustain the system or capability being acquired. This continuous engagement is necessary to ensure a common understanding of program goals, objectives, and activities. The program office and developer SE team should further maintain frequent, effective communication, in accordance with the contract, as they manage and execute program activities and trade-off decisions.

The Program Manager and Systems Engineer focus on the transformation of required operational and sustainment needs into a system design capability. As the design solution evolves through the application of the eight technical processes, the verification component or test organization provides confidence that the design solution that evolved from the requirements analysis, functional allocation, and design synthesis properly addresses the desired capabilities. The Test Engineer, working in tandem with the Systems Engineer, accomplishes the verification loop of the SE process. Together the Systems Engineer and Test Engineer generate and analyze data from the integrated tests. The developer uses the test results to improve system performance, the SE team uses the test results for risk assessments, and the acquisition community and operational evaluators use the test results for operational assessments of the evolving system. This test and evaluation strategy should be consistent with and complementary to the SEP. The Program

Manager and the Systems Engineer work closely with the Test Engineer to facilitate coordinated verification and validation activities.

Stakeholders

The Program Manager has the critical role of approving a systems engineering (SE) approach that includes all stakeholders. The Systems Engineer coordinates with all participants to translate the operational needs and capabilities into technically feasible, affordable, testable, measurable, sustainable, achievable (within scheduled need dates), and operationally effective and suitable system requirements. The Systems Engineer is responsible for planning and overseeing all technical activity within the program office and for managing stakeholder expectations. Early and frequent involvement with stakeholders by both the Program Manager and the Systems Engineer facilitates the successful execution of SE activities throughout the acquisition life cycle.

Most program personnel are involved in one or more of the 16 SE processes. Personnel from non-SE organizations or from outside the program office (e.g., end users, requirements sponsors, maintainers, testers, planners) should be integrated within the program's technical management activities so they have the ability to actively participate throughout the life cycle in support of SE-related activities.

The following is a partial list of the stakeholders that contribute to and benefit from SE activities and processes:

- Warfighters and other end users
- Milestone Decision Authority (MDA)
- Resource sponsors
- Budget authority
- Developers
- Enabled or enabling systems in the system of systems (SoS)
- Security Manager or System Security Engineer
- Chief Developmental Tester
- Operational test organization
- Certification and accreditation authorities
- Logisticians (materiel readiness and sustainment)
- Trainers
- Budget and cost analysts
- Contracting officers and associated staff
- Environment, safety, and occupational health (ESOH) staff
- Contractors who build, test, deploy, and/or support the capability under development
- Companion programs

Integrated Product Teams

An effective SE organization is typically structured as one or more IPTs (refer to the DoD IPPD Handbook for specific examples of functionally integrated IPTs). The IPTs include technical

experts from relevant technical fields and carry out their activities as an integrated effort with a focus on delivering the required capability(ies). In developing the program office and SE organizational structure, the Program Manager and Systems Engineer should know and understand both the design and functions of the developer's technical organization along with the developer's business model (in-house vs. outsourced). This understanding is critical to ensure effective coordination and oversight of developer activities and can affect how meetings are set up and conducted, how configuration management is executed, etc. In some cases, the Program Manager and Systems Engineer may organize multiple IPTs to align with the major products in the program's Work Breakdown Structure. In smaller programs, the SE organization may be organized as a single IPT.

IPTs provide both the Government and developer stakeholders with the opportunity to maintain continuous engagement. This continuous engagement is necessary to ensure a common understanding of program goals, objectives, and activities. These Government/developer IPTs should further maintain effective communication as they manage and execute those activities and trade-off decisions. The program's SE processes should include all stakeholders in order to ensure the success of program efforts throughout the acquisition life cycle.

For Major Defense Acquisition Programs, the Program Manager ensures that the program office is structured to interface with the SE Working-Level Integrated Product Team (SE WIPT) (a multidisciplinary team responsible for the planning and execution of SE) to address DoD leadership concerns and interests. The SE WIPT is chartered by the Program Manager and is usually chaired by the Systems Engineer. The SE WIPT includes representatives from OUSD(AT&L) and the component acquisition executive's organization, both Government and developer IPT leads from the program, the Program Executive Office Systems Engineer, the SoS Systems Engineer, and the developer Systems Engineer. A generic SE WIPT charter is available on the ODASD(SE) Policy and Guidance website under "Guidance and Tools."

4.1.5. Certifications

4.1.5. Certifications

Certifications provide a formal acknowledgment by an approval authority that a system or program meets specific requirements. Certifications, in many cases, are based on statute or regulations and drive systems engineering (SE) planning (i.e., a program may not be able to test or field the capability without certain certifications). Used throughout the acquisition life cycle, certifications reduce program risk and increase understanding of the system. Certain specific certifications are required before additional design, integration, network access, or testing can take place. For example, airworthiness certifications need to be in place before an aircraft can begin flight testing. Often programs insufficiently plan for the number of required certifications. Insufficient planning for certifications can have a negative impact on program costs and schedule.

Obtaining the various certifications can be a lengthy process. As a result, the Program Manager should ensure that the time necessary to obtain any required certification is factored into technical planning. By planning for the activities required to achieve the necessary certifications,

the Program Manager and Systems Engineer can ensure that development of the system continues uninterrupted while the program meets all system certification requirements. Early planning allows the Systems Engineer and technical team to begin interacting with certification authorities, which sets the foundation for communication throughout the development of the system.

The SEP Outline requires programs to provide a certification matrix that identifies applicable technical certifications and when they are required during the acquisition life cycle. Programs should include certification activities and events in the Integrated Master Schedule (IMS) and the Integrated Master Plan (IMP).

A non-exhaustive list of certifications is available on the DASD(SE) website. Furthermore, Program Managers and Systems Engineers should consult both Joint and Service-specific domain experts to determine other certifications that may be required.

4.1.6. Systems Engineering Role in Contracting

4.1.6. Systems Engineering Role in Contracting

The Systems Engineer should actively participate in developing program contract tasks to ensure that the appropriate technical activities are contained and properly scoped in the final contract. Proper scoping of the technical tasks in the Statement of Work (SOW), Statement of Objectives (SOO), or Performance Work Statement (PWS) is necessary to ensure that the final system meets end user's needs. Often contracting activities may appear to be primarily programmatic in nature (e.g., acquisition strategy development, writing requests for proposal, performing market research, developing the Contract Data Requirements List (CDRL)) but, in fact, they reflect technical planning and should be influenced by the desired technical content. For example, technical understanding of data rights can be a key element in planning for modularity and open systems design, or the decision to choose an incremental acquisition strategy depends on generic functionality groupings that may not be appropriate for every system.

The Systems Engineer should contribute to the development of contract incentives and/or incentive approaches that promote an understanding of the technical risks inherent in the selected development approach. Incentives such as award fee may be tied to program performance and progress that may be evaluated during technical reviews, or more frequently the incentive is tied to the completion of a technical review. If that is the case, the developer may have a strong incentive to call the review complete as soon as possible. The Systems Engineer and Program Manager exercise best judgment in an objective and informed manner to ensure the reviews are not prematurely declared completed in order for the developer to qualify for the contract incentive. Another area to which incentives are tied is the Earned Value Management System (EVMS). The Program Manager should ensure that the EVMS tied to any incentive measures the quality and technical maturity of technical work products instead of just the quantity of work. If contracts include earned value (EV) incentives, the criteria should be stated clearly and should be based on technical performance. EV incentives should be linked quantitatively with:

- Technical performance measurement (TPM)

- Progress against requirements
- Development maturity
- Exit criteria of life-cycle phases
- Significant work packages and work products

Additional information about EVMS can be found in DAG Chapter 11 Program Management Activities. The Program Manager should make it a priority to engage with industry to clarify Government expectations and ensure a common understanding of the capability desired, need dates, risks, complexity, and scope. Access to current market information is critical for the program office as it defines requirements for acquisition programs. It is equally important for the contracting officers as they develop acquisition strategies, seek opportunities for small businesses, and negotiate contract terms. The best source of this information is usually found within industry partners. OMB memo, "Myth-Busting: Addressing Misconceptions to Improve Communication with Industry during the Acquisition Process" addresses productive interactions between federal agencies and industry partners. These interactions are strongly encouraged to ensure that the Government clearly understands the marketplace and can award a contract or order for an effective solution at a reasonable price. Early, frequent engagement with industry is especially important for complex, high-risk procurements, including (but not limited to) those for large information technology (IT) projects. Program Managers should develop ways to remove unnecessary barriers to reasonable communication and develop vendor communications plans, consistent with existing law and regulation, which promote responsible exchanges.

The program office uses a Request for Information (RFI) to communicate expectations and plans, including the expected business rhythm for contract execution. This communication ensures the offerors have an opportunity to provide a tight linkage across the Integrated Master Plan (IMP), Work Breakdown Structure (WBS), Integrated Master Schedule (IMS), risk management, and cost in their proposals. Early industry engagement opportunities include pre-solicitation notices, industry days, and other market research venues.

Before releasing the RFP, the program office needs to allow enough time to develop and mature the performance and functional specifications that need to be included in the RFP. The RFP and supporting technical documentation clearly define the Government's expectations in terms of the performance and functional specifications, program planning, program process, risks, and assumptions. The RFP also should direct potential offerors to integrate their approach to reflect the Government's expectations.

It is the responsibility of the Systems Engineer to ensure that technical documents accurately and clearly communicate the Government's requirements including mandatory design, build, test, certification, approval, and acceptance criteria. This ensures the developer is made aware of all required processes and objective quality evidence (OQE) to be produced, to include processes leading to certification, approval, and acceptance using predetermined OQE. In addition, the Program Manager should consider providing all offerors with the IMP and top-level schedule (with internal and external dependencies), expected business rhythm, current risk assessments, and the Systems Engineering Plan (SEP) as part of the RFP.

Although there are many opportunities for contract-related interactions between the Government

and potential offerors prior to contract award, the RFP remains the primary tool for shaping the contract, the program, and ultimately the system. See the "Guide for Integrating Systems Engineering into DoD Acquisition Contracts, Version 1.0, 2006" for additional guidance on the content and format of RFPs.

Within the RFP development team, the Systems Engineer should be responsible for the technical aspects of the RFP and should perform the following actions:

- Reference current required operational documentation and system performance specifications
- Identify SE process requirements (for example, requirements management, configuration management, and risk management; see DAG section 4.3. Systems Engineering Processes)
- Identify any design considerations including production; reliability and maintainability(R&M); environment, safety, and occupational health (ESOH); human systems integration (HSI); and security
- Identify for delivery Government-required technical data rights produced by the developer
- List and describe technical assessment evidence and events, including technical reviews, audits, and certifications and associated entrance/exit criteria
- Specify data protection, SoS, and system testing and verification requirements
- Coordinate with Chief Developmental Tester in regard to the test and evaluation requirements
- Provide a requirements verification traceability database (requirements and test method)
- Specify meetings and technical documentation between the program office and the developer
- Conduct a review of the deliverables (what data, level of detail, data rights, and when needed) and buy only what is needed in concert with should cost goals
- Lead or support the technical evaluation during source selection, to include providing inputs to the development of source selection criteria
- Perform schedule risk assessments as part of the source selection evaluation process
- Support the Independent Management Review (Peer Review) of the RFP before release
- Identify external or SoS interfaces and ensure the technical interface requirement and task scope are unambiguous to the offerors

Table 4.1.6.T1 contains the typical technical contents of the RFP and the associated Systems Engineer's responsibilities, and should not be considered an exhaustive or mandatory list.

Table 4.1.6.T1. Typical Technical Contents of a Request for Proposal (RFP)

	Typical Technical Contents	SE Responsibilities
Section C Description of Work to Be Performed	• Statement of Work (SOW) • System Performance Specification • Operational Documents (CONOPS, SoS, Requirements, etc.) • Engineering processes	• Provide program technical requirements and technical aspects in the SOW • Generate the system performance specification • Identify application of SE processes • Identify appropriate technical specifications and standards
Section H Special Contract Requirements	• Key personnel • Government-furnished equipment or information (GFE or GFI) • Obsolescence management • Warranties • Options for delivery of software • Award fees	• Include a clear statement of any special contract requirements that are not included in other sections of the uniform contract format
Section J Attachments	• Systems Engineering Plan (SEP) • Program Work Breakdown Structure (WBS) • Integrated Master Plan (IMP) • Top-level program schedule • Contract Data Requirements List (CDRL) • Contract security classification specification • Data rights attachment	• Support development of WBS, IMP, top-level program schedule, CDRL, and Contract Security Specification • Ensure that sufficient time is allotted to develop high-quality specifications and plans prior to releasing the RFP
Section K Representations, Certifications, and Other Statements	• Data rights	• Identify provisions that require representations, certifications, or the submission of other information by offerors • Consider including a provision requiring offerors to identify any technical data or computer software the offeror proposes to deliver to the Government after award with less than unlimited rights

	Typical Technical Contents	SE Responsibilities
Section L Instructions on Content and Structure of RFP Response	• Systems engineering solution • Systems engineering management processes • Technical baseline management • Technical reviews and audits • Risk management processes and known key risk areas • Mandatory (i.e., statute- and regulation-driven) and advised design considerations • Technical organization • Technical data required for a Streamlined Life Cycle Assessment (LCA)	• Adequately define the offeror's design • Provide technical background and context for the offeror's solution • Describe the offeror's SE technical and management processes • Provide consistency across the SOW and system specifications • Demonstrate alignment with Government processes
Section M Source Selection Evaluation Factors	• Technical: technical solution, supporting data, performance specification • Management: SOW, Contractor Systems Engineering Management Plan (SEMP), IMS, risks plans • Environmental objectives (when appropriate) • Quality or product assurance • Past performance • Price or cost to the Government • Extent offeror's rights in the data rights attachment meet Government's needs	• Define technical evaluation factors and provide SE specific evaluation criteria used to assess proposals • Participate on or lead the technical evaluation team • Provide technical personnel to participate on each evaluation factor team (e.g., management, past performance, cost) • Provide consistency across the SOW and system specifications • Evaluate RFP responses against technical requirements, threshold requirements, management (e.g., SEMP, WBS, and program schedule), and consistency across the proposal (e.g., link between WBS, program schedule, risks, and cost) • Identify and assess the technical risks for each proposal, including schedule risks and related risk mitigation plans

4.2. Systems Engineering Activities in the Life Cycle

4.2. Systems Engineering Activities in the Life Cycle

This section is split into two major areas.

- DAG sections 4.2.1 - 4.2.7 provide introductory material and describe the Systems Engineer's role in each phase of the weapon system acquisition life cycle. The notional technical reviews and audits in each phase are identified, but the details are left for the

second major area of 4.2.

- DAG section 4.2.8 provides an overview of technical reviews and audits, followed by DAG sections 4.2.9 - 4.2.17 which address each specific technical review and audit. This arrangement accommodates the planning and conducting of the technical reviews and audits in accordance with a program's specific needs. Some large and complex programs may require each technical review and audit; others may combine technical reviews and audits or get permission to tailor them out.

4.2.1. Life-Cycle Expectations

4.2.1. Life-Cycle Expectations

Systems engineering (SE) provides the technical foundation for all acquisition activities regardless of acquisition category (ACAT) or acquisition model (e.g., weapon system or information system). The SE framework described in this chapter spans the entire acquisition life cycle and is based on DoDD 5000.01 and DoDI 5000.02. Framework content should be tailored and structured to fit the technology maturity, risks, interdependencies, related characteristics, and context for the program or the system of interest. The succeeding sections identify the SE activities, processes, inputs, outputs, and expectations during each acquisition phase and for each technical review and audit.

Acquisition milestones and SE technical reviews and audits serve as key points throughout the life cycle to evaluate significant achievements and assess technical maturity and risk. Table 4.2.1.T1 identifies the objectives of each SE assessment and the technical maturity point marked by each review. The Materiel Development Decision (MDD) review is the formal entry point into the acquisition process and is mandatory for all programs in accordance with DoDI 5000.02. Depending on the maturity of the preferred materiel solution, the Milestone Decision Authority (MDA) designates the initial review milestone. This would normally be the MDD, but it can be A, B, or C. In any case the decision is documented in the Acquisition Decision Memorandum (ADM) published immediately after an MDD event. Since the review milestone is chosen consistent with the maturity of the preferred materiel solution, entry at any milestone requires evidence of the associated solution maturity as summarized in Table 4.2.1.T1 Technical Maturity Points.

Department experience (e.g., GAO Report 12-400SP) has found that successful programs use knowledge-based product development practices which include steps to gather knowledge to confirm the program's technologies are mature, their designs are stable, and their production processes are in control. Successful product developers ensure a high level of knowledge is achieved at key junctures in development. Table 4.2.1.T1 summarizes the concept of technical maturity points.

Table 4.2.1.T1. Technical Maturity Points

TECHNICAL MATURITY POINTS			
DoD Acquisition Milestone/Decision Point & Technical Review/Audit	**Objective**	**Technical Maturity Point**	**Additional Information**
Materiel Development Decision (MDD)	Decision to assess potential materiel solutions and appropriate phase for entry into acquisition life cycle.	Capability gap met by acquiring a materiel solution.	Technically feasible solutions have the potential to effectively address a validated capability need. Technical risks understood.
Alternative Systems Review (ASR)	Recommendation that the preferred materiel solution can affordably meet user needs with acceptable risk.	System parameters defined; balanced with cost, schedule, and risk.	Initial system performance established and plan for further analyses supports Milestone A criteria.
Milestone A	Decision to invest in technology maturation and preliminary design.	Affordable solution found for identified need with acceptable technology risk, scope, and complexity.	Affordability targets identified and technology development plans, time, funding, and other resources match customer needs. Prototyping and end-item development strategy for Technology Development (TD) phase focused on key technical risk areas.
System Requirements Review (SRR)	Recommendation to proceed into development with acceptable risk.	Level of understanding of top-level system requirements is adequate to support further requirements analysis and design activities.	Government and contractor mutually understand system requirements including (1) the preferred materiel solution (including its support concept) from the Materiel Solution Analysis (MSA) phase, (2) available technologies resulting from the prototyping efforts, and (3) maturity of interdependent systems.
System Functional Review (SFR)	Recommendation that functional baseline fully satisfies performance requirements and to begin preliminary design with acceptable risk.	Functional baseline established and under formal configuration control. System's functions decomposed and defined to lower levels in order to start preliminary design.	Functional requirements and verification methods support achievement of performance requirements. Acceptable technical risk of achieving allocated baseline.
Preliminary Design Review (PDR)	Recommendation that allocated baseline fully satisfies user requirements and developer ready to begin detailed design with acceptable risk.	Allocated baseline established such that design provides sufficient confidence to support 2366b certification.	Preliminary design and basic system architecture support capability need and affordability target achievement.

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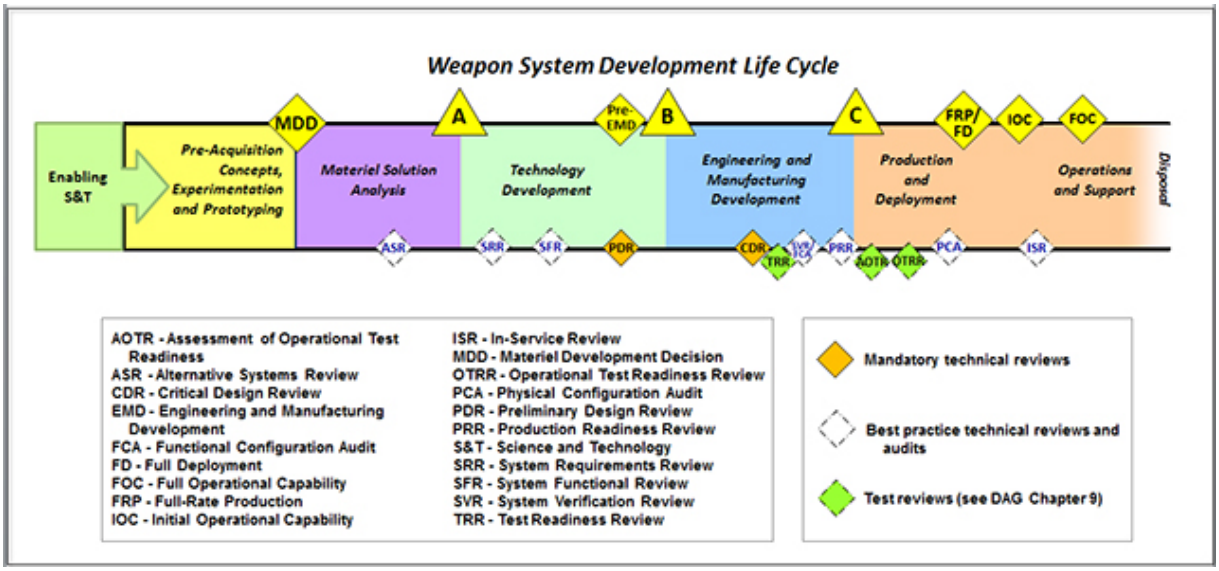
TECHNICAL MATURITY POINTS			
DoD Acquisition Milestone/Decision Point & Technical Review/Audit	**Objective**	**Technical Maturity Point**	**Additional Information**
Pre-Engineering and Manufacturing Development (EMD) Review	Determination that program plans are affordable and executable and that the program is ready to proceed to EMD phase source selection.	Systems engineering trades completed and have informed program requirements. Competitive prototyping and the development of the preliminary design have influenced risk management plans and should cost initiatives.	The Request for Proposal (RFP) reflects the program's plans articulated in the draft Acquisition Strategy and other draft, key planning documents such as the Systems Engineering Plan (SEP), Program Protection Plan (PPP), Test and Evaluation Master Plan (TEMP), and Life-Cycle Sustainment Plan (LCSP).
Milestone B	Decision to invest in product development, integration, and verification as well as manufacturing process development.	Critical technologies assessed able to meet required performance and are ready for further development. Resources and requirements match.	Maturity, integration, and producibility of the preliminary design (including critical technologies) and availability of key resources (time, funding, other) match customer needs. Should cost goals defined.
Critical Design Review (CDR)	Recommendation to start fabricating, integrating, and testing test articles with acceptable risk.	Product design is stable. Initial product baseline established.	Design is stable and performs as expected. Initial product baseline established by the system detailed design documentation confirms affordability/should-cost goals. Government control of Class I changes as appropriate.
System Verification Review (SVR)	Recommendation that the system as tested has been verified (i.e., product baseline is compliant with the functional baseline) and is ready for validation (operational assessment) with acceptable risk.	System design verified to conform to functional baseline.	Actual system (which represents the production configuration) has been verified through required analysis, demonstration, examination, and/or testing. Synonymous with system-level Functional Configuration Audit (FCA).
Production Readiness Review (PRR)	Recommendation that production processes are mature enough to begin limited production with acceptable risk.	Design and manufacturing are ready to begin production.	Production engineering problems resolved and ready to enter production phase.
Milestone C	Decision to produce production-representative units for operational test and evaluation (OT&E).	Manufacturing processes are mature enough to support Low-Rate Initial Production (LRIP) and generate production-representative articles for OT&E.	Production readiness meets cost, schedule, and quality targets. Begin initial deployment as appropriate.

TECHNICAL MATURITY POINTS			
DoD Acquisition Milestone/Decision Point & Technical Review/Audit	**Objective**	**Technical Maturity Point**	**Additional Information**
Physical Configuration Audit (PCA)	Recommendation to start full-rate production and/or full deployment with acceptable risk.	Final product baseline established. Verifies the design and manufacturing documentation matches the item to be fielded, following update of the product baseline to account for resolved OT&E issues.	Confirmation that the system to be fielded matches the product baseline. Product configuration finalized and system meets user's needs. Conducted after OT&E issues are resolved.
Full-Rate Production Decision Review (FRP DR) or Full Deployment Decision Review (FDDR)	Decision to begin full-rate production and/or decision to begin full deployment.	Manufacturing processes are mature and support full-rate production and/or capability demonstrated in operational environment supporting full deployment (i.e., system validated through OT&E).	Delivers fully funded quantity of systems and supporting materiel and services for the program or increment to the users.

Figure 4.2.1.F1 provides the end-to-end perspective and the integration of SE technical reviews and audits across the system life cycle.

Figure 4.2.1.F1. Weapon System Development Life Cycle



The Systems Engineer leads the development and implementation of a technical program strategy. SE processes help deliver capabilities that meet warfighter needs within cost and schedule by balancing end-user needs, design considerations, resource constraints, and risk. The Systems Engineer uses technical reviews and audits to assess whether preplanned technical maturity points are reached during the acquisition life cycle as the system and system elements mature. This knowledge forms the basis for the Systems Engineer's recommendations to the Program Manager on how to technically proceed with the program.

4.2.1.1. Systems Engineering in Other Acquisition Models

4.2.1.1. Systems Engineering in Other Acquisition Models

The acquisition model captured in this version of the DAG Chapter 4 is based on the weapon system model described in DoDI 5000.02 dated December 8, 2008. Other models are being used in the Defense Department which are variations of this model. The anticipated update to DoDI 5000.02 is expected to address these other models. When it is issued, DAG Chapter 4 will be updated accordingly.

4.2.1.2. Systems of Systems

4.2.1.2. Systems of Systems

Whether or not a system is formally acknowledged as a system of systems (SoS), nearly all of our DoD systems function as part of an SoS to deliver a necessary capability to the warfighter (see Systems Engineering Guide for Systems of Systems on the DASD(SE) website). SoS systems engineering (SE) is an ongoing iterative process as shown in the SoS SE Implementers' View in Figure 4.2.1.2.F1. The backbone of SoS SE implementation is continuous analysis that considers changes from the broader environment as well as feedback from the ongoing engineering process. The results of that analysis provide the basis for developing and evolving the SoS architecture, identifying or negotiating changes to the constituent systems that impact the SoS, and working with the constituent systems to implement and integrate those changes. This view of SoS SE implementation provides structure to the evolution of the SoS through changes in constituent systems that are typically on different life-cycle timelines, adapting as systems come in and move out, and as concept of operations (CONOPS) adapt and change. Hence the need for continually updating the SoS analysis and adapting the architecture and updating systems on an ongoing basis.

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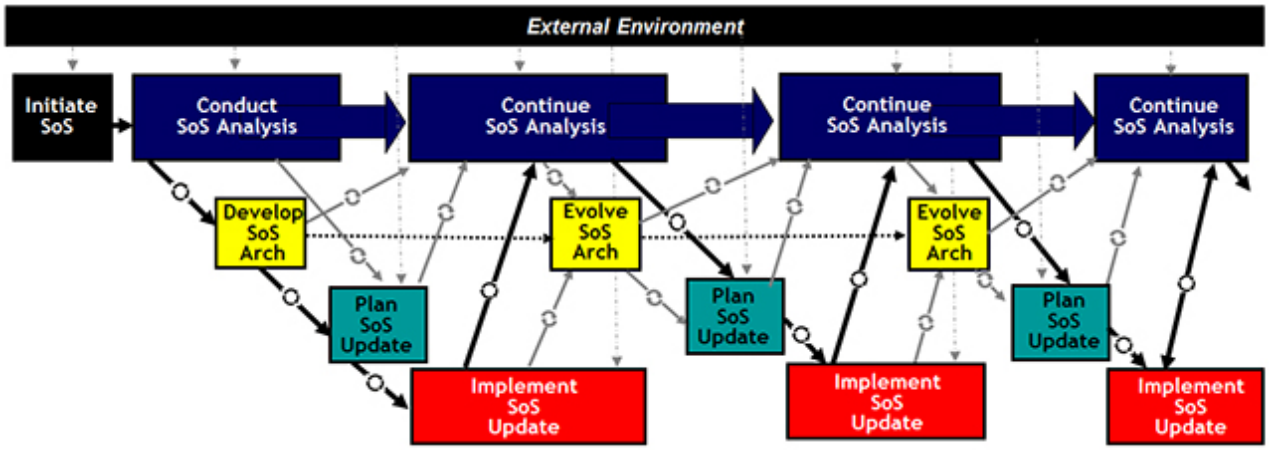
Figure 4.2.1.2.F1. SoS SE Implementers' View



Therefore, SoS SE planning and implementation should consider and leverage the development plans of the individual systems in order to balance SoS needs with individual system needs. Finally, SoS SE should address the end-to-end behavior of the ensemble of systems, addressing the key issues that affect this end-to-end behavior with particular emphasis on integration and interoperability. Effective application of SoS SE addresses organizational as well as technical issues in making SE trades and decisions. The Systems Engineer has different roles and authorities at the system versus the SoS level. The SoS-level Systems Engineer can provide the technical foundation for effective user capabilities by conducting balanced technical management of the SoS, using an SoS architecture based on open systems and loose coupling, and focusing on the design strategy and trades (both at establishment and through evolution). They should collaborate with multiple Systems Engineers across multiple systems. Each Systems Engineer has the authority for their system implementation. These waves of implementations and upgrades taken as a whole provide the SoS capability.

Consideration of SoS in SE for Individual Systems

Most acquisition programs address the development or major upgrade of individual systems (in contrast to SoS). Understanding the SoS context(s) of the system (including use in multiple operational environments) is critical to developing requirements for the system so when delivered it operates effectively in user operational environments. From the Joint Capabilities Integration and Development System (JCIDS) Capabilities-Based Assessment (CBA) through sustainment activities, it is important to recognize how the system context influences system requirements. An up-to-date CONOPS for the system is basic to understanding the system context, notably mission and task threads and data exchanges that have an impact on the system. Systems engineers of individual systems should ensure SoS considerations and risks are addressed throughout the acquisition life cycle by:

- Identifying system dependencies and interoperability needs (See DAG section 4.3.18.13. Interoperability and Dependencies);

- Factoring these into the development of system concepts, requirements, and risks; and
- Addressing these through trade analysis, system architecture and design, interface development and management, and verification and validation.

Both from an individual system perspective and the SoS perspective, Program Managers and Systems Engineers have found it difficult to coordinate and balance the acquisition objectives and strategies for a given system with those of the SoS and other constituent systems. A senior governance body is useful to provide a forum for discussion and decision. This forum should address technical plans, configuration management, and strategies with respect to interfaces, interdependences, risks, and risk mitigation. It is critical to address all equities and make collective decisions that can be implemented in changes to a system's configuration.

One SoS best practice is to monitor closely interdependent programs, with checkpoints at scheduled design reviews to assess program progress, assess related risks, and determine actions to mitigate potentially negative impacts.

Table 4.2.1.2.T1 lists SoS considerations for systems at each stage of acquisition. At each phase, the SE approach to addressing SoS-related dependencies should be addressed in the Systems Engineering Plan (SEP).

Table 4.2.1.2.T1. Key SoS Considerations for Systems by Acquisition Phase

	Pre-MDD	MSA	TD	EMD	P&D and O&S
Focus	• Define role of the system in supporting a mission capability, including relationship to other systems in the SoS which support that capability.	• In the Analysis of Alternatives (AoA), consider the alternatives in the context of the larger SoS supporting the capability. • In the operational analysis and concept engineering for the preferred materiel solution, consider the new system in the SoS context, identify dependencies and relationships with other systems, including key	• Assess the technical approaches and risks for addressing system requirements including considerations for the system as a component operating in a SoS context (including dependencies, interoperability, and interfaces). • Address considerations of changes needed in other systems for the systems in acquisition to meet capability	• Develop, verify, and validate the detailed design that addresses system requirements, considering the SoS context including recognized dependencies and interfaces.	• Verify the as-built interfaces meet specs and support operationa l needs. • Support effective system operation in a SoS context.

		interfaces and technical risks based on SoS considerations to be addressed in Technology Development (TD). • Identify the nature of the dependencies and interfaces, including the parties involved, and an initial plan for addressing these including initial memoranda of agreement (MOAs).	objectives.		
Evidence/Products	• End-to-end depiction (e.g., mission thread) of capability gap in context of systems currently supporting capability	• AoA criteria or results relevant to SoS dependencies or interfaces • Definition of key system dependencies or interfaces that influence system requirements • Initial management plans with supporting MOAs, including draft Interface Control Agreements (ICAs) for collaborations with other systems in a SoS • Risks associated with SoS dependencies (both programmatic and technical) and interoperability	• An interface management plan that is a part of a configuration management plan including ICAs • Risks associated with SoS dependencies and interoperability requirements	• Interface documentation, test plans and reports • Progress on MOAs with system's dependencies • Risks associated with SoS dependencies and interoperability requirements	• Test reports

		requirements, including environment, safety, and occupational health (ESOH), and security risks to be accepted by Joint Authorities			
Measure/ Metrics	• Activities supported by the system in relationship to other systems and the context • Physical environment information needs DOTLPF for the system and the SoS • Identification of stakeholders	• SoS-related requirements in draft system specification and/or Pre-A Request for Proposal (RFP) • MOAs with key parties in SoS dependencies or relationships	• Final interface specifications • MOAs and schedule for interface management plan • Progress with respect to schedule and plan milestones • Progress with respect to expected performance.	• Successful development and test of interfaces • Progress with respect to SoS schedule and plan milestones • Progress with respect to expected performance.	• Successful test results
Responsibilities/ Inter-dependencies	• Provided by the JCIDS analysis and the evidence provided at MDD	• Systems engineers of the systems involved in the SoS or SoS SE if one exists (All) • End users • Requirements developers • Program Manager (MOA) • Contracting (RFP)	• System developers of this system and the other systems involved with the dependencies of interface; shared configuration management (CM) • Interface Management Working Group (IMWG) • End users	• Developers • IMWG • Testers • End users	• Developers • Testers • End users

For a more detailed discussion of SE for SoS, refer to the SoS Initiatives page on the DASD(SE) website.

4.2.2. Pre-Materiel Development Decision

4.2.2. Pre-Materiel Development Decision

The objectives of the pre-Materiel Development Decision (MDD) efforts are to obtain a clear understanding of user needs, identify a range of technically feasible candidate materiel solution approaches, consider near-term opportunities to provide a more rapid interim response, and develop a plan for the next acquisition phase, including the required resources. This knowledge supports the Milestone Decision Authority's (MDA) decision to authorize entry into the acquisition life cycle and pursue a materiel solution. An additional objective is to characterize trade space, risks, and mission interdependencies to support the start of the Analysis of Alternatives (AoA).

Policy in this area comes from two perspectives: the Joint Capabilities Integration and Development System (JCIDS) defined in CJCSI 3170.01 and the Defense Acquisition System (DAS) defined in DoDD 5000.01.

DTM 10-017, "Development Planning to Inform Materiel Development Decision (MDD) Reviews and Support Analyses of Alternatives (AoA)", issued September 2010, introduced specific policy on development planning in support of defense acquisition.

Development planning (DP) encompasses the engineering analysis and technical planning activities that provide the foundation for informed investment decisions on the path a materiel development follows to effectively, affordably, and sustainably meet operational needs. Development planning activities are initiated prior to the Materiel Development Decision, continue throughout the Materiel Solution Analysis phase, and eventually transition to the program environment.

Attention to critical systems engineering (SE) processes and functions, particularly during early phases in acquisition, is essential to ensuring that programs deliver capabilities on time and on budget. The effective execution of pre-MDD SE efforts provides the foundation for user-driven requirements and technically feasible solution options that ensure an executable program. At MDD, the MDA not only decides whether an investment is made to fill the capability gap but also determines the fundamental path the materiel development will follow. This decision should be based on effective development planning.

An important aspect of the pre-MDD effort is narrowing the field of possible solutions to a reasonable set that is analyzed in the AoA. Early recognition of constraints, combined with analysis of technical feasibility, can eliminate many initial ideas because they lack the potential to meet the need in a timely, sustainable, and cost-effective manner. Conversely, the range of alternatives analyzed in the AoA are chosen from a sufficiently broad solution space. Whenever possible, the Systems Engineer should try to engage with the end user before the Initial Capabilities Document (ICD) and associated operational architecture is validated by the Joint Requirements Oversight Council (JROC) (see DAG section 4.3.12. Stakeholder Requirements Definition Process).

Studies have found that "programs that considered a broad range of alternatives tended to have better cost and schedule outcomes than the programs that looked at a narrow scope of

alternatives." (Reference GAO-09-665 Analysis of Alternatives, page 6.)

The work performed in this time frame should be well documented so the Program Manager and Systems Engineer, when assigned, can benefit from the mutual understanding of the basis of need (requirements) and the art of the possible (concepts/materiel solutions). To achieve these benefits, the Systems Engineer should proactively collaborate with the Science and Technology (S&T) and user communities.

Roles and Responsibilities

Often there is no assigned Program Manager or Systems Engineer at this point in the weapon system's life cycle. Instead, a designated Service representative is orchestrating and leading the preparations for MDD. This leader, motivated by the entrance criteria for MDD, is responsible for synthesizing the necessary information to satisfactorily address the four policy evidence needs stated in DTM 10-017. For a more detailed discussion of development planning policy, refer to the white paper on the pre-MDD Activities.

The designated Service representative should make use of appropriate models and simulations (DAG section 4.3.19.1 Modeling and Simulation) to develop required MDD evidence. The designated Service representative also should consider issuing a Request for Information (RFI) to industry to help identify and characterize alternative solutions.

Inputs

Table 4.2.2.T1 summarizes the primary inputs and technical outputs associated with this part of the life cycle. Unlike the sections that follow, this pre-MDD period is the bridge between JCIDS and the DAS. It is the period before the pre-systems acquisition period of the DAS.

Table 4.2.2.T1. Inputs Associated with Pre-MDD

Inputs for Pre-MDD
Draft Initial Capabilities Document (ICD) • Product of Capability-Based Assessment (CBA) or equivalent, see CJCSI 3170.01
Other analyses • Other prior analytic, experimental, prototyping, and/or technology demonstration efforts may be provided by the S&T community

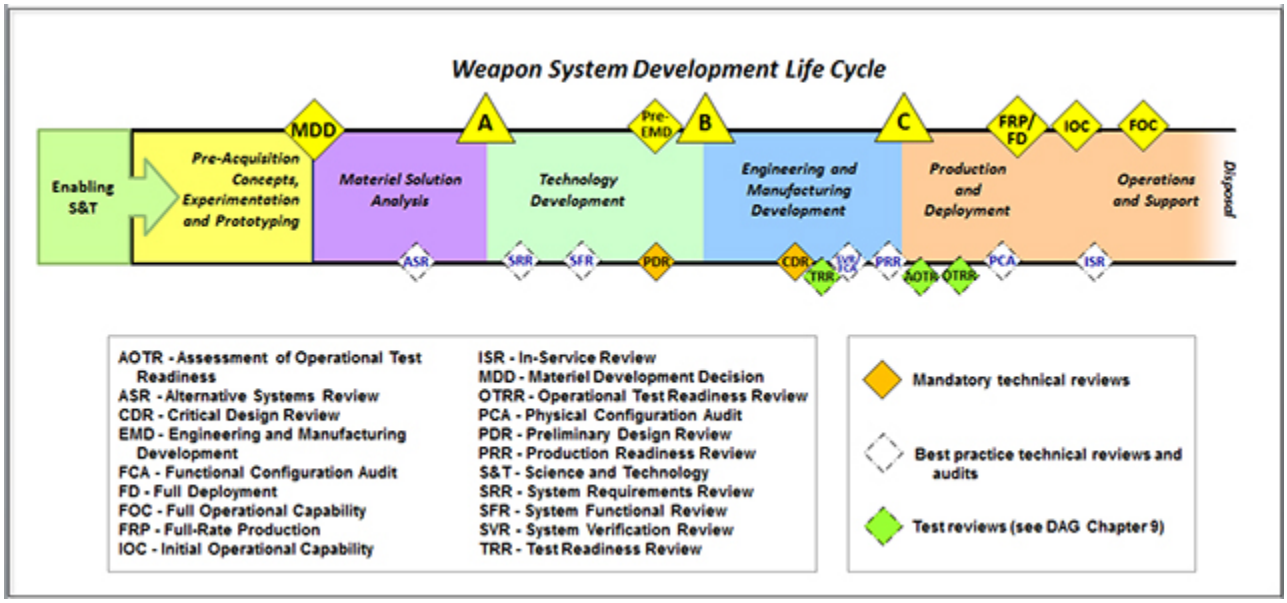
The MDD review requires an ICD that represents an operational capability need validated in accordance with CJCSI 3170.01. The Joint Staff provides this document, which is generally the output of a Capability-Based Assessment (CBA) or other studies. The designated Service representative should have access to both the ICD and supporting studies. Other technical information (such as models and simulations) may be useful for understanding both the need and

its context. The S&T community can contribute pertinent data and information on relevant technologies, prototypes, experiments, and/or analysis. An example is available of how a program may provide evidence at the MDD review to support the MDA decision.

Activities

Figure 4.2.2.F1 provides the end-to-end perspective and the integration of SE technical reviews and audits across the acquisition life cycle.

Figure 4.2.2.F1. Weapon System Development Life Cycle



During pre-MDD, SE activities focus on

- Achieving an in-depth understanding of the operational capability gaps defined in the ICD and identifying the sources of the gap(s) which, if addressed by a materiel solution, could achieve the needed capability
- Identifying an appropriate range of candidate materiel solutions from across the trade space to meet the need
- Identifying near-term opportunities to provide a more rapid interim response to the capability need
- Working with the S&T community (across Government, industry, and academia) as well as other collaborators to build the technical knowledge base for each candidate materiel solution in the AoA Guidance to include experimentation and prototyping
- Analyzing trade space to determine performance versus cost benefits of potential solutions
- Planning for the technical efforts required during the next phase

Outputs and Products

This effort ends after a successful MDD review in which the MDA approves entry into the Defense Acquisition System. This decision is documented in a signed Acquisition Decision Memorandum (ADM), which specifies the approved entry point, typically the Materiel Solution Analysis (MSA) phase. Outputs of pre-MDD efforts provided in Table 4.2.2.T2 also include approved AoA Guidance and an AoA Study Plan, which should be informed by SE.

Table 4.2.2.T2. Technical Outputs Associated with Pre-MDD

Technical Outputs from Pre-MDD
Informed advice to the ICD
Informed advice to the AoA Guidance and Study Plan
Informed advice to the plan and budget for the next phase, including support to the AoA and non-AoA technical efforts required to prepare for the initial milestone review
Informed advice to the ADM

All potential materiel solutions pass through an MDD before entering the DAS. However, the MDA may authorize entry at any point in the acquisition life cycle based on the solution's technical maturity and risk. Technical risk has several elements: technology risk, engineering risk, and integration risk. If the Service-recommended entry point is beyond the MSA phase, for example part way through the Technology Development (TD) phase, the program provides evidence that all MSA and TD phase-specific entrance criteria and statutory requirements are met, and that the solution's technical maturity supports entry at the point in the phase being proposed. Emphasis should be placed on the soundness of supporting technical information and plans in order to inform the MDA's decision, as opposed to which documents may or may not be complete.

As the next section explains, the MSA phase is made up of more than an AoA; it includes technical tasks to determine the preferred materiel solution based on the AoA results and technical tasks to prepare for the initial milestone review. Therefore, the technical plan and budget presented at the MDD should reflect the full range of activities required in the next phase.

4.2.3. Materiel Solution Analysis Phase

4.2.3. Materiel Solution Analysis Phase

The objective of the Materiel Solution Analysis (MSA) phase is to select and adequately describe a preferred materiel solution to satisfy the phase-specific entrance criteria for the next program milestone designated by the Milestone Decision Authority (MDA). Usually, but not always, the next milestone is a decision to invest in technology maturation and preliminary design in the Technology Development (TD) phase. The systems engineering (SE) activities in the MSA phase result in several key products. First, a system model and/or architecture is developed that captures operational context and envisioned concepts, describes the system boundaries and interfaces, and addresses operational and functional requirements. Second, a preliminary system performance specification is developed that defines the performance of the preferred materiel solution. Third, the Systems Engineer advises the Program Manager on what is to be prototyped,

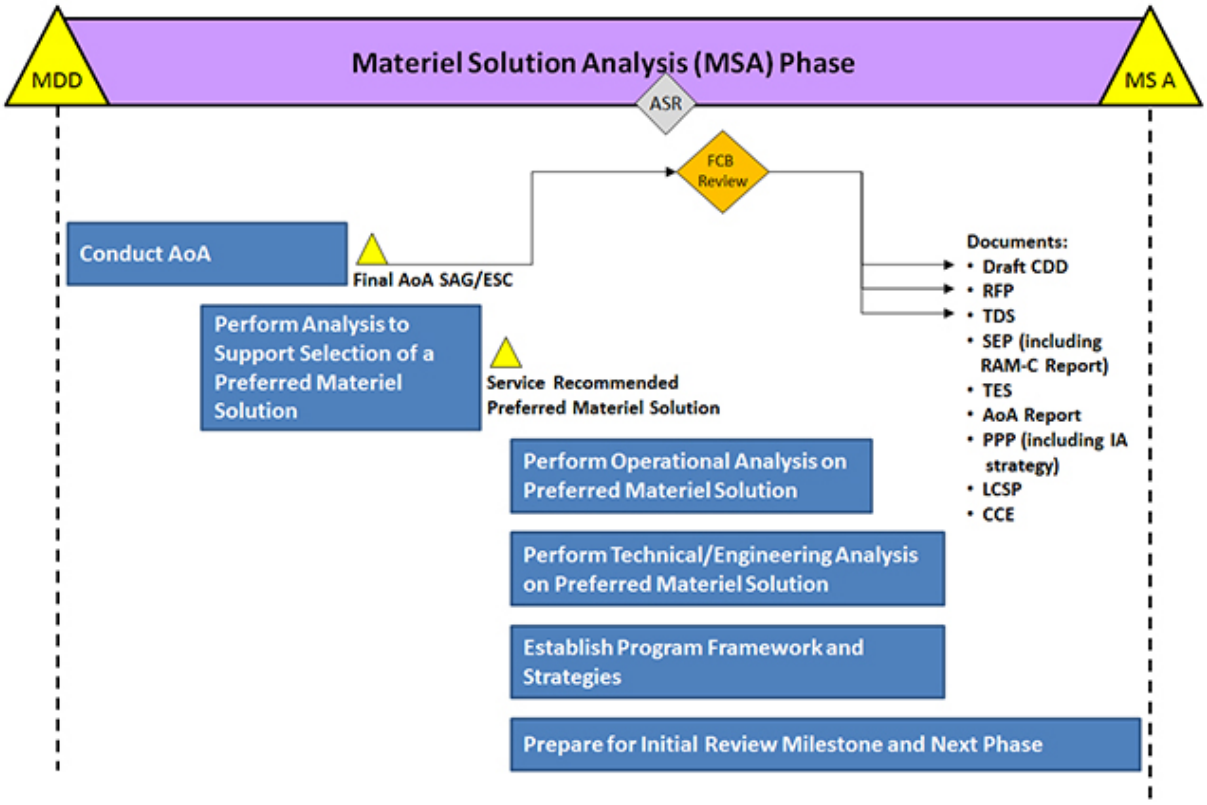
why, and how.

During the MSA phase, the program team identifies a materiel solution to address user capability gaps partially based on an Analysis of Alternatives (AoA) (i.e., analysis of the set of candidate materiel solutions) led by the Director, Cost Analysis and Program Evaluation (CAPE) and conducted by an organization independent from the Program Manager. Once the Service sponsor selects a preferred materiel solution, the program team focuses engineering and technical analysis on this solution to ensure development plans, schedule, funding, and other resources match customer needs and match the complexity of the preferred materiel solution. SE activities should be integrated with MSA phase-specific test, evaluation, logistics, and sustainment activities identified in DAG Chapter 9 Test and Evaluation and Chapter 5 Life-Cycle Logistics.

This phase has two major blocks of activity: (1) the AoA and (2) the post-AoA operational analysis and concept engineering to prepare for a next program milestone designated by the MDA (see Figure 4.2.3.F1).

The AoA team considers a range of alternatives and evaluates them from multiple perspectives as directed by the AoA Guidance and AoA Study Plan. Engineering considerations including technical risk should be a component of the AoA Guidance and be addressed in the AoA Study Plan.

Figure 4.2.3.F1. Activities in Materiel Solution Analysis Phase



The objective of the AoA is to analyze and characterize each alternative (or alternative approach) relative to the others. The AoA does not result in a recommendation for a preferred alternative; it provides information that the Service sponsor uses to select which materiel solution to pursue. The Systems Engineer may participate in the AoA to help analyze performance, feasibility, and to optimize alternatives. Using the AoA results, the Service sponsor may conduct additional engineering analysis to support the selection of a preferred materiel solution from the remaining trade space of candidate materiel solutions. After choosing the preferred materiel solution, the Service sponsor matures the solution in preparation for the next program milestone designated by the MDA.

After the AoA, program systems engineers establish the technical performance requirements consistent with the draft Capability Development Document (CDD), required at next program milestone designated by the MDA, assuming it is Milestone A. These requirements form the basis for the system performance specification placed on contract for the TD Phase. These requirements also inform plans to mitigate risk in the TD phase.

During MSA, several planning elements are addressed to frame the way forward for the MDA's decision at the next program milestone. SE is a primary source for addressing several of these planning elements. The planning elements include:

- Capability need, architecture
- System concept, architecture
- Key interfaces (including external interfaces and dependencies)
- Acquisition approach
- Engineering/technical approach/strategy
- Test and evaluation approach/strategy
- Program management approach
- External dependencies/agreements
- Schedule
- Resources
- Risks

See DAG section 4.3.2. Technical Planning Process. These planning elements are documented in various program plans such as the Technology Development Strategy (TDS), Test and Evaluation Strategy (TES), Program Protection Plan (PPP), next-phase Request for Proposal (RFP), and the Systems Engineering Plan (SEP). The SEP describes the SE efforts necessary to provide informed advice to these other planning artifacts (see the SEP Outline).

SE provides, for example, the technical basis for TD phase planning and execution, including identification of critical technologies, development of a competitive prototyping strategy, and establishment of other plans that drive risk-reduction efforts. This early SE effort lays the foundation for the TD phase contract award(s) and preliminary designs, which confirm the system's basic architecture.

Roles and Responsibilities

In addition to the general responsibilities identified in DAG section 4.1.4. Engineering Resources, the Program Manager focuses on the following MSA activities, which rely on and support SE efforts:

- Prepare for and support source selection activities for the upcoming phase solicitation and contract award
- Support the requirement community with development of the draft CDD, assuming the next phase is TD
- Develop the TDS, which incorporates necessary risk-reduction activities
- Staff the program office with qualified (trained and experienced) systems engineers

In addition to the general roles and responsibilities described in DAG section 4.1.4. Engineering Resources, during this phase it is the Systems Engineer's responsibility to:

- Lead and manage the execution of the technical activities in this phase
- Measure and track program technical maturity
- Identify technologies that should be included in an assessment of technical risk
- Perform trade studies
- Support preparations for the RFP package
- Develop the system performance specification. See DAG section 4.3.7 Configuration Management Process. A particular program's naming convention for specifications should be captured in the SEP and other plans and processes tailored for the program.
- Ensure integration of key design considerations into the system performance specification.
- Develop technical approaches and plans, and document them in the SEP.
- Ensure the phase technical artifacts are consistent and support objectives of the next phase.

Inputs

Table 4.2.3.T1 summarizes the primary inputs associated with this pre-systems acquisition part of the life cycle (see DoDI 5000.02). The table assumes the next phase is TD, but most of the technical outputs would be applicable going into any follow-on phase.

Table 4.2.3.T1. Inputs Associated with MSA Phase

Inputs for MSA Phase
Initial Capabilities Document (ICD) • Product of Capability Based Assessment (CBA) or equivalent. See **CJCSI 3170.01**
AoA Guidance and AoA Study Plan
Acquisition Decision Memorandum (ADM) (may contain additional direction)

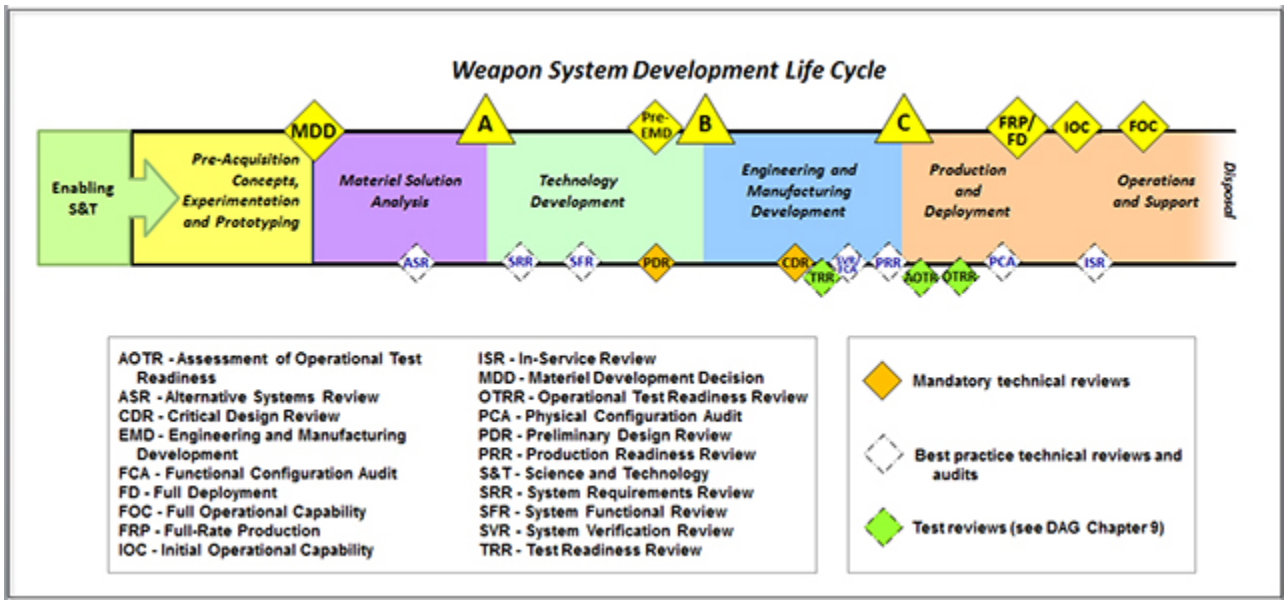
Other analyses
• Other prior analytic, prototyping, and/or technology demonstration efforts conducted by the S&T community; technology insertion/transition can occur at any point in the life cycle

The ICD, AoA Guidance, and AoA Study Plan should be available prior to the start of the MSA phase. Results of other related analyses may be available, for example from the Capability Based Assessment (see DAG section 4.3.10. Stakeholder Requirements Definition Process) or other prior analytic and/or prototyping efforts conducted by the S&T community.

Activities

The MSA phase activities begin after a favorable MDD review has been held (see DAG section 4.2.2. Pre-Materiel Development Decision) and end when the phase-specific entrance criteria for the next program milestone, designated by the MDA, have been met. Figure 4.2.3.F2 provides the end-to-end perspective and the integration of SE technical reviews and audits across the acquisition life cycle.

Figure 4.2.3.F2. Weapon System Development Life Cycle



Referring back to Figure 4.2.3.F1, which shows the major blocks of technical activities in the MSA phase:

- **Conduct AoA.** Includes all activities and analyses conducted by the AoA Study team under the direction of the Senior Advisory Group / Executive Steering Committee (SAG/ESC) and CAPE, or Service equivalent. Concludes with a final ESC/SAG; produces AoA Report. Systems engineers should support this activity, though in DoD policy the AoA is to be conducted by an organization independent from the Program

Manager.

- **Perform Analysis to Support Selection of a Preferred Materiel Solution.** Includes all engineering activities and technical analysis performed to support Service selection of the preferred materiel solution by balancing cost, performance, schedule, and risk.
- **Perform Operational Analysis on Preferred Materiel Solution**. Supports the definition of the performance requirements in the operational context, Functional Capabilities Board (FCB) review, and the development of the draft CDD (see CJCSI 3170.01 Joint Capabilities Integration and Development System (JCIDS) and DAG section 4.3.10. Stakeholders Requirements Definition Process). The Systems Engineer should support the operational requirement/user/operational test community to ensure the concept of operations (CONOPS) is detailed enough to verify and validate system performance and operational capability. This activity could include the development of design reference missions/use cases that assist in the verification and validation process. Through analysis, the Systems Engineer also helps to identify key technology elements, determine external interfaces, establish interoperability requirements, and identify critical program information.
- **Perform Engineering and Technical Analysis on Preferred Materiel Solution.** This includes all engineering activities and technical analysis performed on the Service-selected preferred materiel solution in support of the development and maturation of a materiel solution concept, associated system specification, and technical plans for the next phase.
- **Establish Program Framework and Strategies.** All activities to converge on the overarching strategies and plans for the acquisition and sustainment of the system. Attention should be given to identifying and documenting agreements with external organizations. This documentation should include, for example, the contributions of S&T organizations and plans for transitioning technology into a program.
- **Prepare for Initial Review Milestone and Next Phase.** Includes all activities to compile technical and programmatic analysis and plans to meet the entrance criteria for the next program milestone designated by the MDA. See DoDI 5000.02 for phase exit criteria and PDUSD(AT&L) memorandum, "Improving Milestone Process Effectiveness."

The technical review typically conducted in the MSA phase is the Alternative Systems Review (ASR) (see DAG section 4.2.9. Alternative Systems Review).

For a more detailed discussion of MSA phase activities, refer to the white paper on the MSA Activities Model.

Outputs and Products

The knowledge gained during this phase, based on both the AoA and other analyses, should provide confidence that a technically feasible solution approach matches user needs and is affordable with reasonable risk, see Table 4.2.3.T2. Technical outputs associated with technical reviews in this phase are addressed later in this chapter.

Table 4.2.3.T2. Technical Outputs Associated with MSA Phase

Technical Outputs from MSA Phase
Informed advice to the draft Capability Development Document (CDD)
Informed advice to the AoA Report
Informed advice to the selection of the preferred materiel solution • Selection of the preferred materiel solution is documented in the ADM
Informed advice to the ADM
SEP • PDUSD(AT&L) memorandum, "Document Streamlining - Program Strategies and Systems Engineering Plan," April 20, 2011 • See DAG section 4.1.2 Systems Engineering Plan
Reliability, Availability, Maintainability, and Cost Rationale Report (RAM-C Report) • Attachment to SEP as directed by DTM 11-003
Reliability Growth Curves (RGC) • Attachment to SEP as directed by DTM 11-003
PPP • PDUSD(AT&L) memorandum, "Document Streamlining - Program Protection Plan (PPP)," July 18, 2011 • See DAG Chapter 13 Program Protection
Trade study results • Results could include knees-in-the-curves sensitivity analyses, product selections, etc.
Assumptions and constraints • Rationale for all assumptions, constraints, and basis for trades
Environment, Safety, and Occupational Health (ESOH) planning
Assessment of technical risk
Consideration of technology issues • DoDI 5000.02, Enclosure 4, Tables 2-1 and 2-2
Initial identification of critical technologies
Interdependencies / interfaces / memoranda of agreement (MOAs) • Understanding of the unique program interdependencies, interfaces, and associated MOAs
Draft system performance specification

Technical Outputs from MSA Phase
Other technical information: such as architectures, systems models, and simulations generated during the phase
Prototyping strategy • Relationship between draft system specification and competitive prototyping objectives is established and plans for next phase are consistent with this, both from a competitive prototyping and preliminary system design perspective • Includes identification of key system elements to be prototyped prior to Milestone B • Documented in the TDS as directed by DTM 09-027
Informed advice to Affordability Assessment • Affordability targets are established and treated as Key Performance Parameters (KPPs) at the next program milestone designated by the MDA • Identify the likely design performance points where trade-off analyses occur during the next phase • Value engineering results, as appropriate (see DAG section 4.3.19.3. Value Engineering) • See DAG Chapter 3 Affordability and Life-Cycle Resource Estimates
Informed advice to the Life-Cycle Sustainment Plan (LCSP) • PDUSD(AT&L) memorandum, "Document Streamlining - Life-Cycle Sustainment Plan (LCSP)," September 14, 2011 • See DAG Chapter 5 Life-Cycle Logistics
Informed advice to the Test and Evaluation Strategy (TES) • DOT&E memorandum, "DOT&E TEMP Guidebook," February 27, 2012 • See DAG Chapter 9 Test and Evaluation
Informed advice to the developmental test and evaluation (DT&E) planning including Early Operational Assessments (EOAs) • See DAG Chapter 9 Test and Evaluation
Informed advice to the Request for Proposal (RFP) • Informed advice including system specification, SOW, CDRLs, and source selection criteria
Informed advice to the Technology Development Strategy (TDS) • Informed advice on engineering approaches and strategies, external dependencies, resource requirements, schedule, and risks • PDUSD(AT&L) memorandum, "Document Streamlining - Program Strategies and Systems Engineering Plan," April 20, 2011 • See DAG Chapter 2 Program Strategies

4.2.4. Technology Development Phase

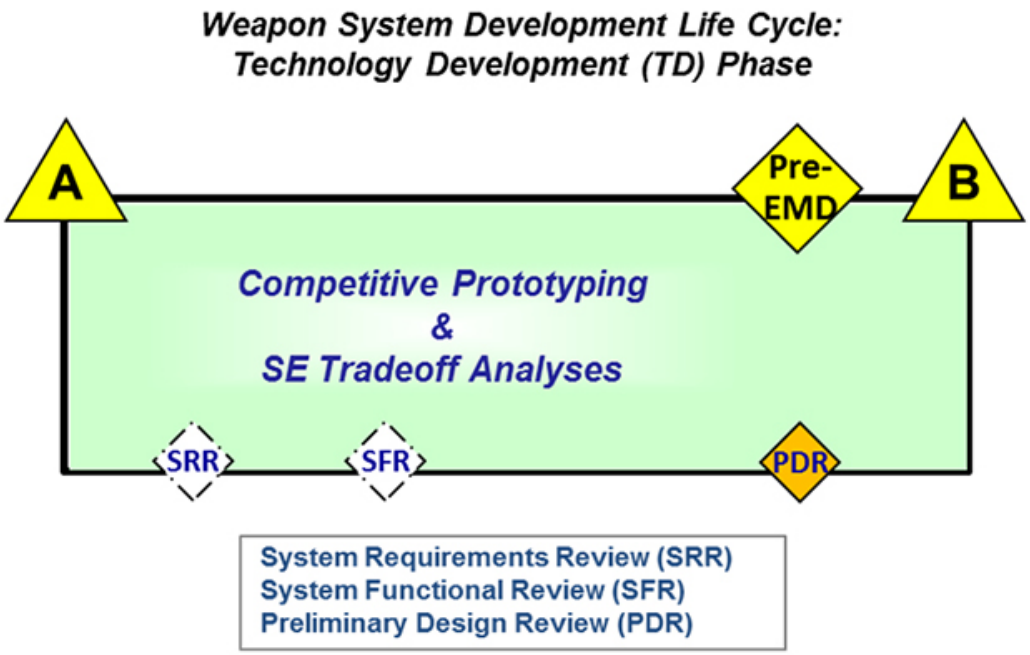
4.2.4. Technology Development Phase

The primary objective of the Technology Development (TD) phase is to reduce technical risk and develop a sufficient understanding of the materiel solution to support sound investment decisions at the pre- Engineering and Manufacturing Development (EMD) Review and at Milestone B regarding whether to initiate a formal acquisition program. The Systems Engineer supports the production of a preliminary system design that achieves a suitable level of system maturity for low-risk entry into EMD (see Figure 4.2.4.F1.). Usually the Systems Engineer implements a strategy of competitive prototyping on a system element or subsystem level, balancing capability needs and design considerations to synthesize system requirements for a preliminary end-item design for the system.

The major efforts associated with the TD phase are:

- Determine the appropriate set of technologies to integrate into a full system
- Mature the technologies including demonstrating and assessing them in a relevant environment
- Conduct competitive prototyping of the system and/or system elements
- Perform trade studies, refine requirements, and revise designs
- Develop the preliminary design, including functional and allocated baselines, specifications, interface control drawings/documents, architectures, and system models
- Perform developmental test, as appropriate

Figure 4.2.4.F1. Systems Engineering Activities in the Technology Development Phase



SE activities should be integrated with TD phase-specific test and evaluation and logistics and sustainment activities identified in DAG Chapter 9 Test and Evaluation and Chapter 5 Life-Cycle Logistics, respectively.

During the TD phase, the program develops and demonstrates prototype designs to reduce technical risk, validate design approaches, validate cost estimates, and refine requirements. In, addition, the TD phase efforts ensure the level of expertise required to operate and maintain the product is consistent with the force structure. Technology development is an iterative process of maturing technologies and refining user performance parameters to accommodate those technologies that do not sufficiently mature (requirements trades). The Initial Capabilities Document, the Technology Development Strategy (TDS), Systems Engineering Plan (SEP), and draft Capability Development Document (CDD) guide the efforts of this phase.

There are two key technical objectives in the TD phase: technical risk reduction and initial system development activity, culminating in preliminary design. The Systems Engineer in the TD phase manages activities to evaluate prototyped solutions (preferably competitive prototypes) against performance, cost, and schedule constraints to balance the total system solution space. This information can then be used to inform the finalization of the system performance specification as a basis for functional analysis and preliminary design.

Effective systems engineering (SE), applied in accordance with the SEP and gated by technical reviews, reduces program risk, identifies potential management issues in a timely manner, and supports key program decisions. The TD phase provides the Program Manager with a preliminary design and allocated baseline that are realistic and credible.

Roles and Responsibilities

The program office team provides technical management and may employ industry, Government laboratories, the Service science and technology (S&T) community, or Federally Funded Research and Development Centers (FFRDCs)/universities to accomplish specific risk-reduction or prototype tasks as described in the SEP.

In addition to the general responsibilities identified in DAG section 4.1.4. Engineering Resources, the Program Manager focuses on the following TD activities, which rely on and support SE efforts:

- Award TD phase contract(s)
- Provide resources for technical reviews
- Plan and execute the Technology Readiness Assessment (TRA)
- Influence development of the CDD
- Develop the Acquisition Strategy (AS)
- Support pre-EMD review
- Ensure the Government preserves the rights they need consistent with the life-cycle acquisition and support strategy; during TD, proprietary development and design can often lead to issues with data rights (see DAG section 4.3.8. Technical Data Management

Process)

In addition to the general roles and responsibilities described in DAG section 4.1.4. Engineering Resources, during this phase it is the Systems Engineer's responsibility to:

- Lead and manage the execution of the technical activities as documented in the SEP
- Plan and execute technical reviews, including the System Requirements Review (SRR), System Functional Review (SFR), and Preliminary Design Review (PDR)
- Measure and track program maturity using technical performance measures, requirements stability, and integrated schedules
- Support award of TD phase contract(s), as necessary
- Balance and integrate key design considerations
- Maintain the Systems Engineering Plan (SEP), including generating the update in support of Milestone B
- Lead initial development of the system to include functional analysis, definition of the functional and allocated baselines, and preliminary design (see DAG sections 4.3.11. Requirements Analysis Process and 4.3.12. Architecture Design Process)
- Support configuration management of the baselines, since they are required in later technical reviews, audits, and test activities (e.g., functional baseline at the Functional Configuration Audits (FCAs))
- Conduct technical activities in support of the pre-EMD review
- Conduct a rigorous and persistent assessment of technical risk, determine risk mitigation plans, and work with the Program Manager to resource the mitigation plans
- Support the Technology Readiness Assessment (TRA) including creation of the plan, the pre-EMD preliminary TRA, and the TRA final report
- Support requirements management and monitor for unnecessary requirements growth (e.g., derived versus implied requirements)
- Manage interfaces and dependencies

Inputs

Table 4.2.4.T1 summarizes the primary inputs associated with this pre-systems acquisition part of the life cycle (see DoDI 5000.02).

Table 4.2.4.T1. Inputs Associated with TD Phase

Inputs for TD Phase
Draft Capability Development Document (CDD)
Analysis of Alternatives (AoA) Report and AoA Sufficiency Report
Preferred materiel solution • Selection of preferred materiel solution is documented in the ADM
Acquisition Decision Memorandum (ADM) (may contain additional direction)

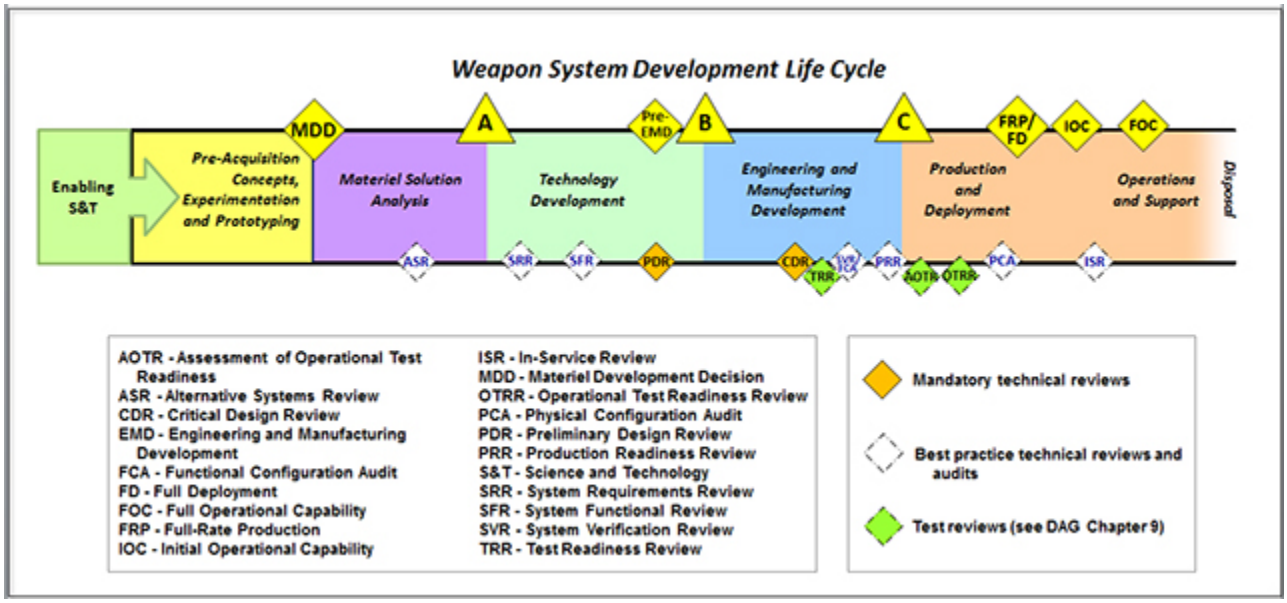
Inputs for TD Phase
SEP • PDUSD(AT&L) memorandum, "Document Streamlining - Program Strategies and Systems Engineering Plan," April 20, 2011 • See DAG section 4.1.2 Systems Engineering Plan
Reliability, Availability, Maintainability, and Cost Rationale (RAM-C) Report • Attachment to SEP as directed by DTM 11-003
Reliability Growth Curves (RGC) • Attachment to SEP as directed by DTM 11-003
Program Protection Plan (PPP) • PDUSD(AT&L) memorandum, "Document Streamlining - Program Protection Plan (PPP)," July 18, 2011 • See DAG Chapter 13 Program Protection
Trade study results • Results could include knees-in-the-curves sensitivity analyses, product selections, etc.
Assumptions and constraints • Rationale for all assumptions, constraints, and basis for trades
Environment, safety, and occupational health (ESOH) planning
Risk assessment
Consideration of technology issues • DoDI 5000.02, Enclosure 4, Tables 2-1 and 2-2
Initial identification of critical technologies • MSA phase may have identified an initial list of critical technologies
Interdependencies / interfaces / memoranda of agreements (MOAs)
Draft system performance specification
Other technical information such as models and simulations generated during the MSA phase
Prototyping strategy • Includes identification of key system elements to be prototyped prior to Milestone B, see DTM 09-027

Inputs for TD Phase
Affordability Assessment • Affordability targets are established and treated as a Key Performance Parameters (KPPs) at Milestone A • Affordability targets drive engineering trade-offs and sensitivity analyses about capability priorities in the TD phase • See DAG Chapter 3 Affordability and Life-Cycle Resource Estimates
TDS • PDUSD(AT&L) memorandum, "Document Streamlining - Program Strategies and Systems Engineering Plan," April 20, 2011 • See DAG Chapter 2 Program Strategies
Life Cycle Sustainment Plan (LCSP) • PDUSD(AT&L) memorandum, "Document Streamlining - Life-Cycle Sustainment Plan (LCSP)," September 14, 2011 • See DAG Chapter 5 Life-Cycle Logistics
Test and Evaluation Strategy (TES) • DOT&E memorandum, "DOT&E TEMP Guidebook," February 27, 2012 • See DAG Chapter 9 Test and Evaluation
Informed advice to the developmental test and evaluation (DT&E) assessments • Includes Early Operational Assessments (EOAs) • See DAG Chapter 9 Test and Evaluation
Draft and final Request for Proposal (RFP)
Security Classification Guide (SCG)
Other analyses • Other prior analytic, prototyping, and/or technology demonstration efforts done by the S&T community. Technology insertion/transition can occur at any point in the life cycle

Activities

The TD phase activities begin when a favorable Milestone A decision has been made (see DAG section 4.2.3. Materiel Solution Analysis Phase) and end with a successful Milestone B decision. Figure 4.2.4.F2 provides the end-to-end perspective and the integration of SE technical reviews and audits across the acquisition life cycle.

Figure 4.2.4.F2. Weapon System Development Life Cycle



The TD phase addresses a set of critical activities leading to the decision to establish a program of record. The SE activities provide the technical foundation for this decision. Depending on the nature of the technology development strategy, the order and characteristics of these activities may change. During the TD phase, systems engineers follow comprehensive, iterative processes to accomplish the following:

- **Perform Competitive Prototyping**. As mentioned earlier, prototyping is an engineering technique employed for several reasons. Competitive prototyping (CP) has as a primary objective to acquire more innovative solutions at better value by ensuring competition. At this point in the life cycle, the CP strategy should focus on mitigating key technical risk areas. The program office should have a clear understanding of technical, engineering, and integration risks at Milestone A. Current policy does not require full-up system prototypes; therefore, competitive prototyping may include prototyping critical technologies, system elements, integration of system elements, or full-up prototypes. Because a primary objective of this type of prototyping is to support a follow-on award choice between developers, contract incentives should be aligned to CP strategy goals. Contract goals should require the solutions demonstrated during CP be used in the subsequent PDR/CDR designs. The CP strategy should be identified in the SEP and TDS, tasks specified in RFPs/Task Orders, technically managed by the program office, and included in the TES with specific test objectives.
- **Perform Technology Maturation**. The TDS identifies technologies requiring further maturation before they can be implemented within a solution. Technology maturation involves design, development, integration, and testing. There could be one or more risk areas related to hardware, software, or information technology, and there may be multiple industry contracts/Government efforts for maturing the technology. The TES should stipulate the test and evaluation approach for assessing the results of the technology maturation activities (see DAG Chapter 9 Test and Evaluation ; Chief Developmental

Tester). The Systems Engineer participates in the technology readiness assessment (TRA). The TRA focuses only on technology maturity as opposed to engineering and integration risk. DoDI 5000.02 and OSD TRA Guidance provide policy and guidance for TRAs.

- **Perform System Trade Analysis**. The Systems Engineer assesses alternatives with respect to performance, cost, schedule and risk, and makes a recommendation to the Program Manager. The SE assessment should consider the full range of relevant factors, for example affordability targets, technology maturity, development and fielding constraints, and user-identified needs and shortfalls. System trades should be used to inform and shape the CDD and cost and schedule objectives to be documented in the Acquisition Program Baseline (APB).
- **Develop System Architecture.** See DAG section 4.3.12. Architecture Design Process for additional information.
- **Develop Functional Baseline.** See DAG section 4.3.7. Configuration Management Process for additional information.
- **Develop Allocated Baseline.** See DAG section 4.3.7. Configuration Management Process for additional information.
- **Develop Preliminary Design.** See DAG section 4.2.12. Preliminary Design Review for additional information.
- **Develop Allocated Technical Performance Measures (TPMs).** The allocated baseline establishes the first physical representation of the system as subsystem elements with system-level capabilities allocated to subsystem-level technical performance measures.
- **Complete PDR Report.** After the PDR, the Program Manager develops the PDR Report with support from the Systems Engineer. The Program Manager provides the report to the MDA to support a Milestone B decision. The report includes recommended requirements trades based upon an assessment of cost, schedule, performance, and risk.
- **Support pre-EMD review.** The purpose of the MDA-level review is to assess the AS, RFP, and key related planning documents and determine whether program plans are affordable and executable and reflect sound business arrangements. Specific SE attention is given to engineering trades and their relationship to program requirements and risk management.
- **Finalize Documents.** The Systems Engineer updates the SEP and PPP and provides inputs for updating the LCSP, TEMP, and other program documents.

Technical reviews typically conducted in the TD phase are:

- System Requirements Review (SRR) (see DAG section 4.2.10. System Requirements Review)
- System Functional Review (SFR) (see DAG section 4.2.11. System Functional Review)
- Software Specification Review (SSR) for programs with significant software development; a SSR is typically performed before, and in support of, a PDR. The SSR technical assessment establishes the software requirements baseline for the system elements under review (e.g., computer software configuration items (CSCI)) to ensure their preliminary design and ultimately the software solution has a reasonable expectation of being operationally effective and suitable.
- Preliminary Design Review (PDR) mandated (unless formally waived) to confirm the

development of the allocated baseline (see DAG section 4.2.12. Preliminary Design Review)

Test activities during the TD phase that depend on SE support and involvement include developmental test and evaluation of system and/or system element prototypes and Early Operational Assessments (EOAs). Developmental Test and Evaluation (DT&E) activities, for example, should be closely coordinated between the engineering and test communities since DT&E activities support:

- Technical risk identification, risk assessment, and risk mitigation;
- Providing empirical data to validate models and simulations; and
- Assessing technical performance and system maturity (see DAG Chapter 9 Test and Evaluation).

Outputs and Products

The technical outputs identified in Table 4.2.4.T2 are some of the inputs necessary to support SE activities in the EMD phase. The outputs should support the technical recommendation at Milestone B that an affordable solution has been found for the identified need with acceptable risk, scope, and complexity. Technical outputs associated with technical reviews in this phase are addressed later in this chapter.

Table 4.2.4.T2. Technical Outputs Associated with TD Phase

Technical Outputs from TD Phase
Informed advice to CDD
Informed advice to Acquisition Decision Memorandum (ADM) and 2366a certification
Preliminary system design • Updated functional and allocated baselines • Associated technical products including associated design and management decisions
SEP (updated) • If programs enter the acquisition life cycle at Milestone B, this is their initial SEP • PDUSD(AT&L) memorandum, "Document Streamlining - Program Strategies and Systems Engineering Plan," April 20, 2011 • See DAG section 4.1.2 Systems Engineering Plan
Updated Integrated Master Plan (IMP), Integrated Master Schedule (IMS), and memoranda of agreement (MOAs)/ memoranda of understanding (MOUs)
RAM-C Report (updated) • Attachment to SEP as directed by DTM 11-003; if programs enter the acquisition life cycle at Milestone B, this is their initial RAM-C Report

Technical Outputs from TD Phase
RGC (updated) • Attachment to SEP and TEMP as directed by DTM 11-003
PPP (updated) • If programs enter the acquisition life cycle at Milestone B, this is their initial PPP • PDUSD(AT&L) memorandum, "Document Streamlining - Program Protection Plan (PPP)," July 18, 2011 • See DAG Chapter 13 Program Protection
Trade study results • Results could include knees-in-the-curves sensitivity analyses, product selections, etc.
Assumptions and constraints • Rationale for all assumptions, constraints, and basis for trades • Interdependencies defined
Environment, safety, and occupational health (ESOH) analyses • Programmatic Environment, Safety, and Occupational Health Evaluation (PESHE) and NEPA/EO 12114 Compliance Schedule
Assessment of technical risk • Include SoS risks associated with governance, interdependencies, and complexity
Consideration of technology issues • See DoDI 5000.02, Enclosure 4, Tables 2-1 and 2-2.
Technology Readiness Assessment (TRA) • TRA Plan • Confirmation at the end of TD phase that critical technologies have been demonstrated in a relevant environment • Preliminary TRA required at pre-EMD review • TRA final report
Interdependencies / interfaces / memoranda of agreement (MOAs) • Understanding of the unique program interdependencies, interfaces, and associated MOAs
Updated system performance specification
System preliminary design including functional baseline and allocated baseline
Other technical information such as models and simulations generated during the TD phase

Technical Outputs from TD Phase
Prototyping strategy and results of TD prototyping activities • Including identification of key system elements to be prototyped in EMD Phase and documented in the Acquisition Strategy (AS)
Preliminary Design Review (PDR) Report and Post PDR Assessment (produced by DASD(SE) for MDAPs) • See DoDI 5134.16 • See DTM 09-025 • See DAG Chapter 10 Decisions, Assessments, and Periodic Reporting
Informed advice to Acquisition Program Baseline (APB) • APB inputs include the SE affordability assessments, schedule inputs, and performance inputs
Establishes technical information that is the basis of the cost analysis requirements description (CARD) and manpower estimates
Informed advice to Affordability Assessment • Affordability targets continue to be treated as KPPs at Milestone B; results of engineering trade-off analyses showing how the program established a cost-effective design point for cost/affordability drivers • Should cost goals defined at Milestone B to achieve efficiencies and control unproductive expenses without sacrificing sound investment in product affordability • Value engineering results, as appropriate (see DAG section 4.3.19.3. Value Engineering) • See DAG Chapter 3 Affordability and Life-Cycle Resource Estimates
Informed advice to Acquisition Strategy (AS) • Informed advice on engineering approaches and strategies, external dependencies, resource requirements, schedule, and risks • PDUSD(AT&L) memorandum, "Document Streamlining - Program Strategies and Systems Engineering Plan," April 20, 2011 • See DAG Chapter 2 Program Strategies
Informed advice to LCSP (updated) • System support and maintenance objectives and requirements established; updated will cost values and affordability targets as documented in the Life-Cycle Sustainment Plan (LCSP), including Informed advice to manpower estimates • PDUSD(AT&L) memorandum, "Document Streamlining - Life-Cycle Sustainment Plan (LCSP)," September 14, 2011 • See DAG Chapter 5 Life-Cycle Logistics
Initial Information Support Plan (ISP) • See DAG Chapter 7 Acquiring Information Technology, Including National Security Systems

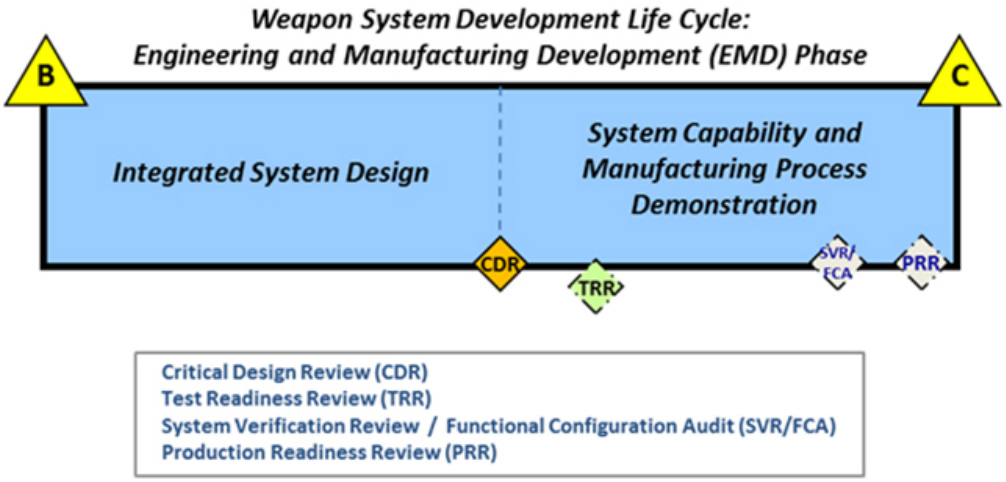
Technical Outputs from TD Phase
Informed advice to Test and Evaluation Master Plan (TEMP) • DOT&E memorandum, "DOT&E TEMP Guidebook," February 27, 2012 • See DAG Chapter 9 Test and Evaluation
Early developmental test and evaluation (DT&E) assessments, including Early Operational Assessments (EOAs) • See DAG Chapter 9 Test and Evaluation
Informed advice to draft and final Request for Proposal (RFP) • Informed advice including system specification, SOW, CDRLs, and source selection criteria

4.2.5. Engineering and Manufacturing Development Phase

4.2.5. Engineering and Manufacturing Development Phase

The primary objective of the Engineering and Manufacturing Development (EMD) phase is to develop the product baseline, verify it meets the system functional and allocated baselines, and transform the preliminary design into a producible design, all within the schedule and cost constraints of the program. Systems engineering (SE) activities support development of the detailed design, verification that requirements are met, reduction in system-level risk, and assessment of readiness to begin production and/or deployment. The core SE activities support the two efforts associated with the EMD phase as defined in DoDI 5000.02 for weapon systems acquisition and identified in figure 4.2.5.F1: integrated system design and system capability and manufacturing process demonstration.

Figure 4.2.5.F1. Systems Engineering Activities in the Engineering and Manufacturing Development Phase



Primary SE focus areas in EMD include:

- Complete the detailed build-to design of the system
- Establish the product baseline
- Conduct integration and tests of system elements and the system (where feasible)
- Demonstrate system maturity and readiness to begin production for operational test and /or deployment and sustainment activities

The EMD phase includes technical assessment and control efforts, including value engineering techniques described in DAG section 4.3.19.3. Value Engineering, to effectively manage risks and increase confidence in meeting system performance, schedule, and cost goals. SE activities should be integrated with EMD phase-specific test and evaluation and logistics and sustainment activities identified in DAG Chapter 9 Test and Evaluation and Chapter 5 Life-Cycle Logistics, respectively. The planning, scheduling, and conduct of event-driven technical reviews (Critical Design Review (CDR), Functional Configuration Audit (FCA), System Verification Review (SVR), and Production Readiness Review (PRR)) are vital to provide key points for assessing program maturity and the effectiveness of risk-reduction strategies.

A well-planned EMD phase Systems Engineering Plan (SEP) builds on the results of previous activities and significantly increases the likelihood of a successful program compliant with the approved Acquisition Program Baseline (APB).

Implementing the technical planning as defined in the approved SEP guides the execution of the complex and myriad tasks associated with completing the detailed design and integration, and supports developmental test and evaluation activities. The SEP also highlights the linkage between Technical Performance Measures (TPM), risk management, and earned-value management activities to support tracking of cost growth trends. Achieving predefined EMD technical review criteria provides confidence that the system meets stated performance requirements (including interoperability and supportability requirements) and that design and development have matured to support the initiation of the Production and Deployment (P&D) phase.

Roles and Responsibilities

In addition to the general responsibilities identified in DAG section 4.1.4. Engineering Resources, the Program Manager focuses on the following EMD activities, which rely on and support SE efforts:

- Conduct activities in support of the EMD contract award
- Resource and conduct event-driven CDR, FCA, SVR, and PRR, and assess whether review criteria are met
- Establish and manage the initial product baseline established at the CDR
- Determine path forward on all major (Class I) baseline changes (see DAG section 4.3.7. Configuration Management Process for definition of Class I)
- Accept system deliveries (i.e., DD-250), as appropriate

In addition to the general roles and responsibilities described in DAG section 4.1.4 Engineering Resources, during this phase it is the Systems Engineer's responsibility to:

- Manage the system design to satisfy the operational requirements within the constraints of cost and schedule and to evaluate the system design, identify deficiencies, and make recommendations for corrective action
- Conduct or support the technical evaluation in support of source selection for the EMD contract award
- Maintain requirements traceability and linkage to the initial product baseline
- Conduct event-driven technical reviews, advising the Program Manager on review criteria readiness
- Lead preparation and conduct of technical reviews
- Track and report major (Class I) baseline changes and recommend the path forward in accordance with the Configuration Management (CM) process (see DAG section 4.3.7. Configuration Management Process for definition of Class I)
- Support determination of production rates and delivery schedules
- Support test and evaluation activities: identify system evaluation targets driving system development and support operational assessments as documented in the Test and Evaluation Master Plan (TEMP) (see DAG Chapter 9 Test and Evaluation)
- Align the SEP with the TEMP on SE processes, methods, and tools identified for use during test and evaluation
- Analyze deficiencies discovered from operational assessments and verification methods (developmental test and evaluation); develop and implement solutions to including, but not limited to, rebalancing of system requirements
- Support logistics and sustainment activities as documented in the Life-Cycle Sustainment Plan (LCSP) (see DAG Chapter 5 Life-Cycle Logistics)
- Maintain the SEP including generating the update in support of Milestone C
- Ensure manufacturing process development and maturation efforts
- Develop approaches and plans to verify mature fabrication and manufacturing processes and determine manufacturing readiness (see the Manufacturing Readiness Level (MRL) Deskbook as one source for assessing manufacturing readiness)
- Conduct a rigorous production risk assessment and determine risk mitigation plans
- Identify system design features that enhance producibility (efforts usually focus on design simplification, fabrication tolerances, and avoidance of hazardous materials)
- Conduct producibility trade studies to determine the most cost-effective fabrication and manufacturing process
- Assess Low-Rate Initial Production (LRIP) feasibility within program constraints (may include assessing contractor and principal subcontractor production experience and capability, new fabrication technology, special tooling, and production personnel training requirements)
- Identify long-lead items and critical materials
- Support update to production costs as a part of life-cycle cost management
- Continue to support the configuration management process to control changes to the product baseline during test and fielding

Inputs

Table 4.2.5.T1. summarizes the primary inputs associated with this systems acquisition part of the life cycle (see DoDI 5000.02).

Table 4.2.5.T1. Inputs Associated with EMD Phase

Inputs for EMD Phase
Capability Development Document (CDD)
Acquisition Decision Memorandum (ADM) (may contain additional direction)
SEP • If programs enter the acquisition life cycle at Milestone B, this is their initial SEP • PDUSD(AT&L) memorandum, "Document Streamlining - Program Strategies and Systems Engineering Plan," April 20, 2011 • See DAG section 4.1.2 Systems Engineering Plan
Reliability, Availability, Maintainability, and Cost Rationale (RAM-C) Report • Attachment to SEP as directed by DTM 11-003; if programs enter the acquisition life cycle at Milestone B, this is their initial RAM-C Report
Reliability Growth Curves (RGCs) • Attachment to TEMP as directed by DTM 11-003
Program Protection Plan (PPP) • If programs enter the acquisition life cycle at Milestone B, this is the initial PPP • Includes Security Classification Guide (SCG), Counterintelligence Support Plan, Criticality Analysis, Anti-Tamper Plan, and Acquisition Information Assurance (IA) Strategy • PDUSD(AT&L) memorandum, "Document Streamlining - Program Protection Plan (PPP)," July 18, 2011 • See DAG Chapter 13 Program Protection
Trade study results • Results could include knees-in-the-curves sensitivity analyses, product selections, etc.
Assumptions and constraints • Rationale for all assumptions, constraints, and basis for trades • Interdependencies defined
Environment, safety, and occupational health (ESOH) analyses • Programmatic Environment, Safety, and Occupational Health Evaluation (PESHE) and NEPA/EO 12114 Compliance Schedule

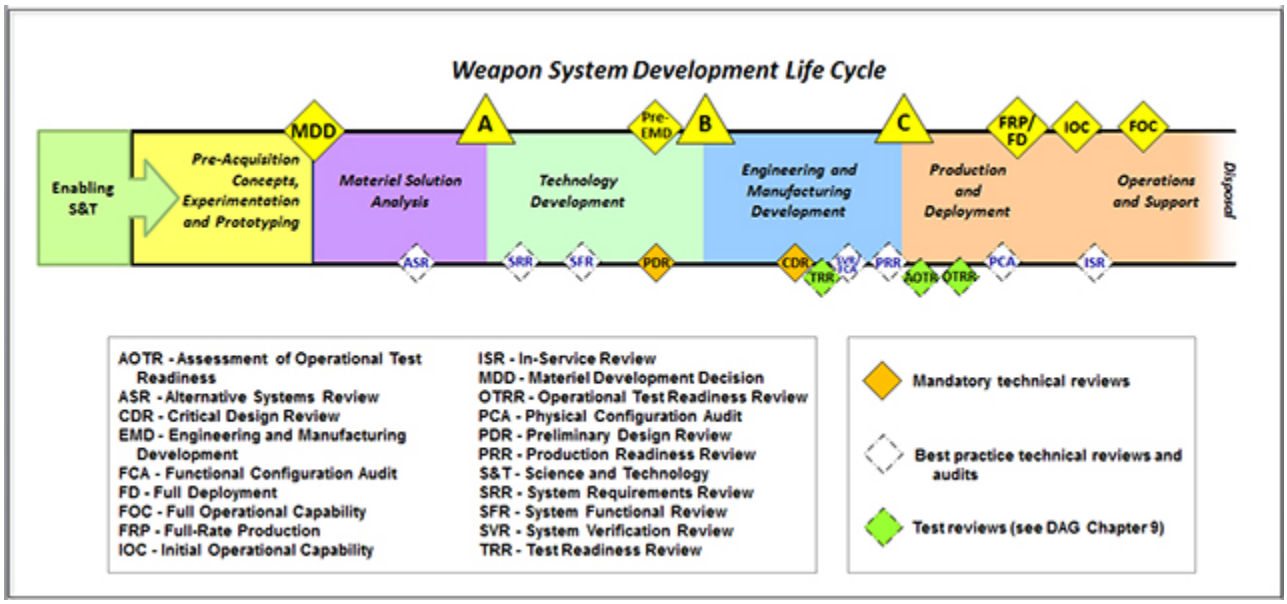
Inputs for EMD Phase
Assessment of technical risk
Consideration of technology issues • See DoDI 5000.02, Enclosure 4, Tables 2-1 and 2-2
Technology Readiness Assessment (TRA) • Confirmation that critical technologies have been demonstrated in a relevant environment
Interdependencies / interfaces / memoranda of agreement (MOAs)
System performance specification including verification matrix
Other technical information such as models and simulations generated during the TD phase
Prototyping strategy
System Threat Assessment Report (STAR)
Acquisition Program Baseline (APB)
Affordability Assessment • Affordability targets treated as KPPs; results of engineering trade-off analyses show cost/schedule/performance trade space around affordability drivers • Should cost goals designed to achieve efficiencies and control unproductive expenses without sacrificing sound investment in product affordability • See DAG Chapter 3 Affordability and Life-Cycle Resource Estimates
Acquisition Strategy (AS) • PDUSD(AT&L) memorandum, "Document Streamlining - Program Strategies and Systems Engineering Plan," April 20, 2011 • See DAG Chapter 2 Program Strategies
Life-Cycle Sustainment Plan (LCSP) (updated) • PDUSD(AT&L) memorandum, "Document Streamlining - Life-Cycle Sustainment Plan (LCSP)," September 14, 2011 • See also DAG Chapter 5 Life-Cycle Logistics
Initial Information Support Plan (ISP) • See DAG Chapter 7 Acquiring Information Technology, Including National Security Systems
Test and Evaluation Master Plan (TEMP) • System Test Objectives • See DOT&E memorandum, "DOT&E TEMP Guidebook," February 27, 2012 • See DAG Chapter 9 Test and Evaluation

Inputs for EMD Phase
Informed advice to the developmental test and evaluation (DT&E) planning including Operational Assessments (OAs) • System test objectives • See DAG Chapter 9 Test and Evaluation
Draft and final Request for Proposal (RFP)
Security Classification Guide (SCG) (updated)
Other analyses • Other prior analytic, prototyping, and/or technology demonstration efforts performed by the S&T community. Technology insertion/transition can occur at any point in the life cycle

Activities

The EMD phase activities begin when a favorable Milestone B decision has been made (see DAG section 4.2.4. Technology Development Phase) and end with a successful Milestone C decision. Figure 4.2.5.F2 provides the end-to-end perspective and the integration of SE technical reviews and audits across the acquisition life cycle.

Figure 4.2.5.F2. Weapon System Development Life Cycle



SE activities to support the integrated system design effort include:

- Realization of the system architecture
- Performance of system element trade-offs
- Use of prototypes to mature system designs and drawings. If the program strategy includes competitive development, this may include competitive prototyping during the

EMD phase.

- Development of the initial product baseline and a stable design that conforms to program cost, schedule, and performance requirements
- Support for the establishment of the developmental test and evaluation environment and associated resources (e.g., people, equipment, test cases, and test ranges)
- Support of materiel readiness and logistical support efforts
- Preparation for production by identifying critical manufacturing processes, key product characteristics, and any manufacturing risks

SE activities to support the system capability and manufacturing process demonstration effort include:

- Build, integrate, and test system elements
- Fabricate and assemble the system elements and system to the product baseline
- Identify the process to proactively manage and mitigate Diminishing Manufacturing Sources and Material Shortages (DMSMS) issues in future life-cycle phases
- Integrate the system and verify compliance with the functional and allocated baselines through developmental test and evaluation (DT&E) efforts (see DAG Chapter 9 Test and Evaluation for more on DT&E)
- Determine the root cause of problems, identify corrective actions, and manage to completion
- Address problem/failure reports through the use of a comprehensive data-collection approach such as Failure Reporting, Analysis and Corrective Action System (FRACAS)
- Refine the initial product baseline and support the development of the Capability Production Document (CPD)
- Complete producibility activities supporting manufacturing readiness or implementation and initial deployment activities for information systems
- Support initiation of materiel readiness and logistical support activities including fielding options and training development
- Perform Environment, Safety, and Occupational Health (ESOH) risk management analyses and ESOH risk acceptance
- Produce NEPA/EO 12114 documentation
- Perform corrosion risk assessment
- Complete certifications as appropriate (see DAG section 4.1.5. Certifications)

Technical reviews and audits typically conducted in EMD:

- Critical Design Review (CDR) (mandated, establishes initial product baseline, see DAG section 4.2.13. Critical Design Review)
- System Verification Review/Functional Configuration Audit (SVR/FCA) (see DAG section 4.2.14. System Verification Review/Functional Configuration Audit)
- Production Readiness Review (PRR) (DAG section 4.2.15. Production Readiness Review)

Test activities during the EMD phase that depend on SE support and involvement include Test Readiness Reviews (TRRs), Developmental Test and Evaluation (DT&E), and Operational

Assessments (OAs). The Systems Engineer, in collaboration with the Chief Developmental Tester, should identify system evaluation targets driving system development and support operational assessments as documented in the Test and Evaluation Master Plan (TEMP). Associated SE activities and plans should be in the SEP (see DAG section 4.1.2. Systems Engineering Plan, 4.2.8. Technical Reviews and Audits Overview, and DAG Chapter 9 Test and Evaluation).

Outputs and Products

The technical outputs and products identified in Table 4.2.5.T2 and are some of the inputs necessary to support SE processes in the P&D phase. They should support the technical recommendation at Milestone C that manufacturing processes are mature enough to support Low-Rate Initial Production (LRIP) and generate production-representative articles for operational test and evaluation (OT&E). Technical outputs associated with technical reviews in this phase are addressed later in this chapter.

Table 4.2.5.T2. Technical Outputs Associated with EMD Phase

Technical Outputs from EMD Phase
Informed advice to CPD
Informed advice to Acquisition Decision Memorandum (ADM) and 2366b certification
Verified system • Updated functional, allocated, and product baselines; verified production processes, and verification results/ decisions • Associated technical products including associated design and management decisions
SEP (updated) • PDUSD(AT&L) memorandum, "Document Streamlining - Program Strategies and Systems Engineering Plan," April 20, 2011 • See DAG section 4.1.2 Systems Engineering Plan
Updated IMP, IMS, and MOAs/MOUs
RAM-C Report (updated) • Attachment to SEP as directed by DTM 11-003
RGC (updated) • Attachment to TEMP as directed by DTM 11-003

Technical Outputs from EMD Phase
PPP (updated) • PDUSD(AT&L) memorandum, "Document Streamlining - Program Protection Plan (PPP)," July 18, 2011) • See DAG Chapter 13 Program Protection
Trade study results • Results could include knees-in-the-curves sensitivity analyses, product selections, etc.
Assumptions and constraints • Rationale for all assumptions, constraints, and basis for trades • Interdependencies updated
ESOH analyses • Updated Programmatic Environment, Safety, and Occupational Health Evaluation (PESHE) and NEPA/E.O. 12114 Compliance Schedule
Assessment of technical risk • Risk assessment identifying mitigation plans for acceptable risks to allow the program to initiate production, deployment, and operational test and evaluation activities • Update system of systems (SoS) risks associated with governance, interdependencies, and complexity
Consideration of technology issues • See DoDI 5000.02, Enclosure 4, Tables 2-1 and 2-2
Manufacturing readiness • Assessment of manufacturing readiness supports MS C and initiation of production • Manufacturing processes have been effectively demonstrated in a pilot line environment
Interdependencies / interfaces / memoranda of agreement (MOAs) • Understanding of the unique program interdependencies, interfaces, and associated MOAs
System performance specification (updated if necessary) including verification matrix • System element specifications including verification matrix
Product baseline
Other technical information such as models and simulations generated during the EMD phase
Results of EMD prototyping activities
Manufacturing prototyping activities support P&D phase

Technical Outputs from EMD Phase
Post-Critical Design Review (CDR) Assessment (produced by DASD(SE) for Major Defense Acquisition Programs)
Informed advice to APB • Updated will cost values and affordability targets as documented in the Acquisition Program Baseline and Acquisition Strategy
Establishes technical information that is the basis of the updates to the Cost Analysis Requirements Description (CARD) and manpower estimates
Informed advice to Affordability Assessment • Should cost goals updated to achieve efficiencies and control unproductive expenses without sacrificing sound investment in product affordability. • Value engineering results, as appropriate. See DAG section 4.3.19.3. Value Engineering. • See DAG Chapter 3 Affordability and Life-Cycle Resource Estimates
Manufacturing, performance, and quality metrics critical to program success are identified and tracked • 30%, 60%, and 100% completed manufacturing drawings
Production budget/cost model validated and resources considered sufficient to support LRIP and FRP • Inputs to MS C, LRIP, and FRP DR
Informed advice to Acquisition Strategy (AS) • Informed advice on engineering approaches and strategies, external dependencies, resource requirements, schedule, and risks • PDUSD(AT&L) memorandum, "Document Streamlining - Program Strategies and Systems Engineering Plan," April 20, 2011 • See DAG Chapter 2 Program Strategies
Informed advice to LCSP (updated) • System Support and Maintenance Objectives and Requirements established • Updated will cost values and affordability targets as documented in the LCSP, including Informed advice to manpower estimates • Confirmation of logistics and sustainment needs (i.e., facilities, training, support equipment) and implementation supporting initial deployment efforts • PDUSD(AT&L) memorandum, "Document Streamlining - Life-Cycle Sustainment Plan (LCSP)," September 14, 2011 • See also DAG Chapter 5 Life-Cycle Logistics
ISP of Record • See DAG Chapter 7 Acquiring Information Technology, Including National Security Systems

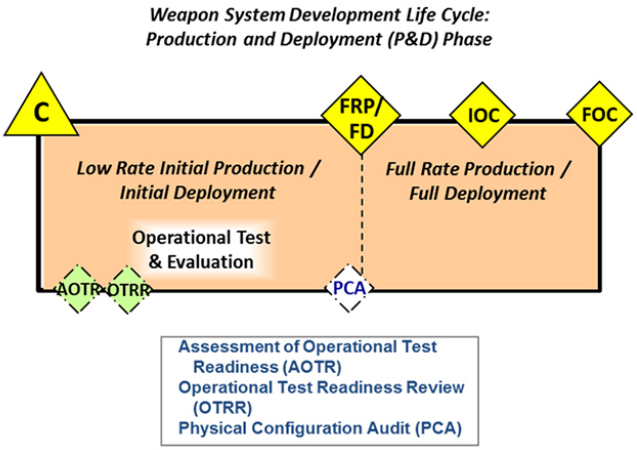
Technical Outputs from EMD Phase
Informed advice to TEMP (updated) • System test objectives • See DOT&E memorandum, "DOT&E TEMP Guidebook," February 27, 2012 • See DAG Chapter 9 Test and Evaluation
Informed advice to the DT&E assessments • System test objectives • See DAG Chapter 9 Test and Evaluation
Informed advice to draft & final RFP for LRIP • Informed advice including system specification, SOW, CDRLs, and source selection criteria

4.2.6. Production and Deployment Phase

4.2.6. Production and Deployment Phase

The objective of the Production and Deployment (P&D) phase is to validate the product design and to deliver the quantity of systems required for full operating capability, including all enabling system elements and supporting material and services. Systems engineering (SE) in P&D delivers the final product baseline as validated during operational testing, and supports deployment and transition of capability to all end users, the warfighters, and supporting organizations. SE activities, for example maintenance approach, training, and technical manuals, should be integrated with P&D phase-specific test and evaluation and logistics and sustainment activities identified in DAG Chapter 9 Test and Evaluation and Chapter 5 Life-Cycle Logistics, respectively. This phase typically has several major efforts as shown in Figure 4.2.6.F1: Low-Rate Initial Production (LRIP), Operational Test and Evaluation (OT&E), Full-Rate Production (FRP) and Full Deployment (FD), and deployment of capability in support of the Initial and Full Operational Capabilities. The Full-Rate Production Decision Review (FRP DR) and/or Full Deployment Decision Review (FD DR) serves as a key decision point between LRIP (and OT&E) and FRP/FD.

Figure 4.2.6.F1. Production and Deployment Phase



Manufacturing development should be complete at Milestone C, but improvements or redesigns may require unanticipated, additional manufacturing process development and additional testing (e.g., delta qualification or delta first article test). For example, it may be discovered that changing the product design may provide enhancements in manufacturing or other supporting processes. At the conclusion of LRIP, all manufacturing development should be completed, with no significant manufacturing risks carried into FRP. The dynamic nature of the varied production elements requires a proactive approach to mitigate emerging risks.

Readiness for OT&E is a significant assessment of a system's maturity (see DAG Chapter 9 Test and Evaluation). The Systems Engineer plays a key role in ensuring systems are ready to enter OT&E. Scarce resources are wasted when an operational test is halted or terminated early because of technical problems that should have been resolved before the start of OT&E.

During deployment, units attain Initial Operational Capability (IOC), then Full Operational Capability (FOC).

Besides ensuring a successful FOC, the SE activities:

- Mature manufacturing, production, and deployment procedures
- Respond to deficiencies and develop corrective actions
- Support validation of system performance associated with OT&E
- Validate the production configuration prior to FRP / FD

Roles and Responsibilities

In addition to the general responsibilities identified in DAG section 4.1.4. Engineering Resources, the Program Manager focuses on the following P&D activities, which rely on and support SE efforts:

- Conduct activities in support of the production contract award(s)

- Resource and conduct event-driven technical reviews (including the Physical Configuration Audit (PCA), Post Implementation Review (PIR), and FRP and/or FD DR) and ensure that criteria are met
- Manage and control the final product baseline
- Manage risks, in particular the manufacturing, production, and deployment risks
- Accept system deliveries (i.e., DD-250)

In addition to the general responsibilities identified in DAG section 4.1.4. Engineering Resources, the Systems Engineer is responsible to:

- Analyze deficiencies discovered from OT&E, acceptance tests, production reports, and maintenance reports and provide correction actions
- Conduct rigorous production risk assessments; plan and resource effective risk mitigation actions
- Continue conducting producibility trade studies to determine the most cost-effective fabrication/manufacturing process
- Develop approaches and plans to validate fabrication/manufacturing processes
- Assess full-rate production feasibility within program constraints. This may include assessing contractor and principal subcontractor production experience and capability, new fabrication technology, special tooling, and production personnel training requirements
- Identify long-lead items and critical materials; plan for obsolescence and implement DMSMS measures to mitigate impacts to production and sustainment
- Update production costs as a part of life-cycle cost management
- Support updates to the production schedules
- Support technical reviews and production decisions
- Support materiel readiness and logistical activities, including fielding and training
- Continue to support the Configuration Management Board to control changes to the product baseline during test and fielding
- Update and maintain system certifications and interfaces with external systems, as necessary

Inputs

Table 4.2.6.T1 summarizes the primary inputs associated with this systems acquisition part of the life cycle.

Table 4.2.6.T1. Inputs Associated with P&D Phase

Inputs for P&D Phase
Capability Production Document (CPD)
Acquisition Decision Memorandums (ADM) associated with Milestone C, LRIP, and FRP DR and FD DR • ADMs may contain additional direction • Milestone C may not coincide with LRIP • FRP DR and FD DR ADMs are issued during P&D phase
SEP • Updated functional, allocated, and product baselines; verified and validated production processes, and validation results / decisions • Updated technical products including associated design and management decisions • PDUSD(AT&L) memorandum, "Document Streamlining - Program Strategies and Systems Engineering Plan," April 20, 2011 • See DAG section 4.1.2 Systems Engineering Plan
Reliability, Availability, Maintainability, and Cost Rationale (RAM-C) Report • Attachment to SEP as directed by DTM 11-003
Reliability growth curves (RGCs) • Attachment to TEMP as directed by DTM 11-003
PPP • Updated at FRP DR and/or FD DR • PDUSD(AT&L) memorandum, "Document Streamlining - Program Protection Plan (PPP)," July 18, 2011 • See DAG Chapter 13 Program Protection
Trade study results • Results could include knees-in-the-curves sensitivity analyses, product selections, etc. • P&D phase trade studies may support manufacturing or other system mods (technology insertion, technology refresh, etc.)
Assumptions and constraints • Rationale for all assumptions, constraints, and basis for trades
Environment, Safety, and Occupational Health (ESOH) analyses • Programmatic Environment, Safety, and Occupational Health Evaluation (PESHE) and NEPA/EO 12114 Compliance Schedule

Inputs for P&D Phase
Risk assessment • Risk mitigation plans • Acceptable risks for achieving Initial Operational Capability (IOC) and Full Operational Capability (FOC) • Updated Risk Management Plan to reflect change from acquisition to deployment and initiation of sustainment activities
Consideration of technology issues • See DoDI 5000.02, Enclosure 4, Tables 2-1 and 2-2
Manufacturing readiness • Assessment of manufacturing readiness supports MS C and initiation of production
Interdependencies / interfaces / memoranda of agreement (MOAs) • Understanding of the unique program interdependencies, interfaces, and associated MOA
System performance specification (updated if necessary) including verification matrix • System element specifications (updated if necessary) including verification matrix
Manufacturing, performance and quality metrics critical to program success are identified and tracked • 30%, 60%, and 100% completed manufacturing drawings
Initial product baseline
Product acceptance test
Other technical information such as models and simulations generated during the EMD phase
Results of EMD prototyping activities
Manufacturing prototyping activities supporting P&D phase
System Threat Assessment Report (STAR)
Acquisition Program Baseline (APB)
Affordability Assessment • Affordability targets treated as KPPs • Should cost goals to achieve efficiencies and control unproductive expenses • Updated will cost values and affordability targets as documented in the Life-Cycle Sustainment Plan (LCSP), including informed advice to manpower estimates • Value engineering results, as appropriate (see DAG section 4.3.19.3. Value Engineering) • See DAG Chapter 3 Affordability and Life-Cycle Resource Estimates
Supply chain sources
Updated Manufacturing processes
Production budget/cost model validated and resources considered sufficient to support LRIP and FRP

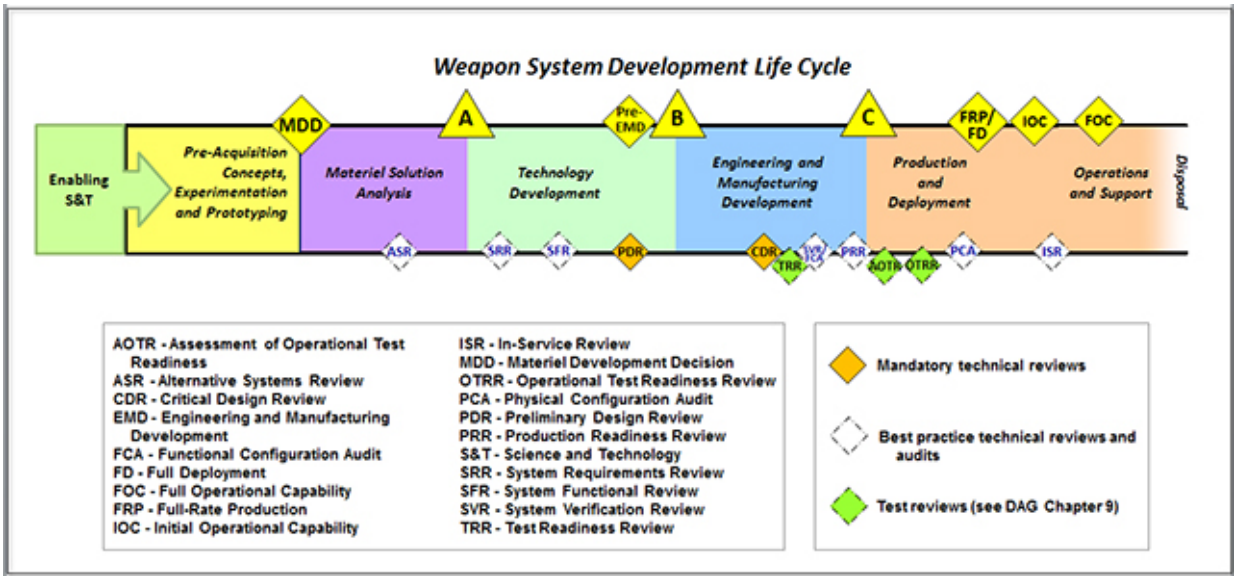
Inputs for P&D Phase
Acquisition Strategy (AS) • PDUSD(AT&L) memorandum, "Document Streamlining - Program Strategies and Systems Engineering Plan," April 20, 2011 • See DAG Chapter 2 Program Strategies
LCSP • PDUSD(AT&L) memorandum, "Document Streamlining - Life-Cycle Sustainment Plan (LCSP)," September 14, 2011 • See DAG Chapter 5 Life-Cycle Logistics
Human Systems Integration (HSI) analyses • Manpower, personnel, and training (MPT) requirement updates • Refinement of HSI inputs to specifications, human system interfaces design, multi-domain verification, testing, and usability evaluations • See DAG Chapter 6 Human Systems Integration
TEMP • System test objectives • See DOT&E memorandum, "DOT&E TEMP Guidebook," February 27, 2012 • See DAG Chapter 9 Test and Evaluation
Developmental test and evaluation (DT&E) assessments • System test objectives • See DAG Chapter 9 Test and Evaluation
Draft and final RFP
Security Classification Guide (SCG)
Information Support Plan (ISP) of Record • See DAG Chapter 7 Acquiring Information Technology, Including National Security Systems
Other analyses • Other prior analytic, prototyping, and/or technology demonstration efforts completed by the science and technology (S&T) community; technology insertion/transition can occur at any point in the life cycle

Activities

The P&D phase SE activities begin when a favorable Milestone C decision has been made (see DAG section 4.2.5. Engineering and Manufacturing Development Phase) and end when FOC is achieved. Figure 4.2.6.F2 provides the end-to-end perspective and the integration of SE technical

reviews and audits across the acquisition life cycle.

Figure 4.2.6.F2. Weapon System Development Life Cycle



SE activities that occur throughout the P&D phase include:

- Provide technical support to prepare for the Operations and Sustainment (O&S) phase, reviewing and providing inputs on the maintenance approach, acquisition strategy, training, and technical manuals
- Determine root cause of problems, identify corrective actions, and manage to completion
- Analyze system deficiencies generated during OT&E, acceptance testing, production, and deployment
- Address problem/failure reports through the use of a comprehensive data collection approach like a Failure Reporting, Analysis and Corrective Action System (FRACAS)
- Manage and control of configuration updates (hardware, software, and specifications) to the product baseline
- Re-verify and validate production configuration

SE provides inputs to OT&E readiness assessments including:

- Results of prior DT&E
- Analysis of the system's progress in achieving performance metrics (see DAG section 4.3.4. Technical Assessment Process)
- Assessment on satisfaction of approved OT&E entrance criteria
- Assessment of technical risk
- Assessment of software maturity and status of software trouble reports
- Identification of any potential design constraints affecting the system's expected performance during OT&E

In both the Production and Deployment and O&S phases the Systems Engineer should identify and plan for potential obsolescence impacts (i.e., Diminishing Manufacturing Sources and Material Shortages (DMSMS)). DMSMS problems are an increasing concern as the service lives of DoD weapon systems are extended and the product life cycle for high-technology system elements decreases.

The PCA is a SE audit typically conducted in the P&D phase (see DAG section 4.2.16. Physical Configuration Audit for additional information regarding the PCA).

Test activities during the P&D phase that depend on SE support and involvement include the Assessment of Operational Test Readiness (AOTR) for MDAPs, Operational Test Readiness Reviews (OTRRs), initial and follow-on OT&E (IOT&E and FOT&E), and live-fire test and evaluations (LFT&E), as appropriate (see DAG Chapter 9 Test and Evaluation). In addition, any corrective actions or design changes implemented in response to test identified deficiencies require additional regression testing.

The Systems Engineer, in collaboration with the Chief Developmental Tester, should identify technical support needed for operational assessments and document in the Test and Evaluation Master Plan (TEMP). Associated SE activities and plans should be in the SEP (see DAG section 4.1.2. Systems Engineering Plan, 4.2.8. Technical Reviews and Audits Overview, and DAG Chapter 9 Test and Evaluation).

Outputs and Products

The technical outputs and products from the P&D phase identified in Table 4.2.6.T2 are some of the inputs necessary to support SE processes in the O&S phase. They should support the program's transition into full operations and sustainment. Technical outputs associated with technical reviews in this phase are addressed later in this chapter.

Table 4.2.6.T2. Technical Outputs Associated with P&D Phase

Technical Outputs from P&D Phase
Informed advice to CPD Update • CPD may be updated to justify system enhancements and modifications from the P&D phase
Informed advice to ADM
Updated IMP, IMS, and MOAs/MOUs
Validated system • Updated functional, allocated, and product baselines; verified and validated production processes, and validation results / decisions • Associated technical products including associated design and management decisions

Technical Outputs from P&D Phase
PPP (updated) • Updated at FRP DR and/or FD DR • PDUSD(AT&L) memorandum, "Document Streamlining - Program Protection Plan (PPP)," July 18, 2011 • See DAG Chapter 13 Program Protection
Trade study results • P&D Phase trade studies may support manufacturing or other system mods (technology insertion, technology refresh, etc.)
Assumptions and constraints • Rationale for all assumptions, constraints, and basis for trades
ESOH analyses • Updated Programmatic Environment, Safety, and Occupational Health Evaluation (PESHE) and NEPA/EO 12114 Compliance Schedule
Assessment of technical risk (updated) • Risk assessment identifying mitigation plans, acceptable risks for achieving FOC • Updated Risk Management Plan (RMP) to reflect change from acquisition to sustainment
Interdependencies / interfaces / memoranda of agreement (MOAs) • Understanding of the unique program interdependencies, interfaces, and associated MOA
System performance specification (updated if necessary) including verification matrix; system element specifications (updated if necessary) including verification matrix
Manufacturing and production metrics
PCA results and an updated product baseline
Acceptance test data to assess product conformance and to support DD250 of end items
Other technical information such as models and simulations generated during the P&D phase
Technical information that is the basis of the updates to the Cost Analysis Requirements Description (CARD) and manpower estimates
Industrial base capabilities; updated manufacturing processes and supply chain sources
Informed advice to Life-Cycle Sustainment Plan (LCSP) • Updated at FRP DR and/or FDDR • Updated will cost values and affordability targets as documented in the LCSP, including informed advice to manpower estimates • Value engineering results, as appropriate (see DAG section 4.3.19.3. Value Engineering) • PDUSD(AT&L) memorandum, "Document Streamlining - Life-Cycle Sustainment Plan (LCSP)," September 14, 2011 • See DAG Chapter 5 Life-cycle Logistics

Technical Outputs from P&D Phase
Human Systems Integration (HSI) analyses • Final manpower and personnel requirements • Training program implementation • HSI participation in Engineering Change Proposal (ECP) process • See DAG Chapter 6 Human Systems Integration
Informed advice to TEMP (updated) • System Test Objectives • DOT&E memorandum, "DOT&E TEMP Guidebook," February 27, 2012 • See DAG Chapter 9 Test and Evaluation
Operational Test and Evaluation (OT&E) Assessments/Reports • System Test Objectives • See DAG Chapter 9 Test and Evaluation
Draft and final RFP(s) for production and SE support to O&S activities

4.2.7. Operations and Support Phase

4.2.7. Operations and Support Phase

The objective of the Operations and Support (O&S) phase is to execute a support program that meets operational support performance requirements and sustains the system in the most cost-effective manner over its total life cycle. Planning for this phase begins in the Materiel Solution Analysis (MSA) phase, matures through the Technology Development (TD) and Engineering and Manufacturing Development (EMD) phases, and is documented in the Life-Cycle Sustainment Plan (LCSP). Systems engineering (SE) in the O&S phase assesses whether the fielded system and enabling system elements continue to provide the needed capability in a safe, sustainable, and cost-effective manner. SE efforts consist of data collection, assessment, and corrective action cycles to maintain a system's operational suitability and operational effectiveness.

Sustainment activities supporting system operations begin in this phase and should address two major efforts: life-cycle sustainment and disposal. SE efforts during life-cycle sustainment include Environment, Safety, and Occupational Health (ESOH) assessments, technology refresh, functionality modification, and life-extension modifications.

When the system no longer provides an effective or efficient capability to the warfighter, the Department should make an informed decision to either modify or dispose of it. However, a related proactive aspect in the Production and Deployment and O&S phases is engineering analysis to identify potential obsolescence impacts (i.e., Diminishing Manufacturing Sources and Material Shortages (DMSMS)). DMSMS problems are an increasing concern as the service lives of DoD weapon systems are extended and the product life cycle for high-technology system elements decreases (see DAG section 4.3.18.8 Diminishing Manufacturing Sources and Material

Shortages).

Roles and Responsibilities

In addition to the general responsibilities identified in DAG section 4.1.4. Engineering Resources, the Program Manager focuses on the following O&S activities, which rely on and support SE efforts:

- Work with the user to document performance and sustainment requirements in performance agreements specifying objective outcomes, measures, resource commitments, and stakeholder responsibilities
- Employ effective Performance-Based Life-Cycle Product Support implementation and management
- Maintain operational readiness
- Follow acquisition program practices for major modifications or Service Life Extension Program (SLEP)

In addition to the general responsibilities identified in DAG section 4.1.4. Engineering Resources, the Systems Engineer is responsible for the following tasks:

- Refine the maintenance program to minimize total life-cycle cost while achieving readiness and sustainability objectives
- Assess end-user feedback and conduct engineering investigations as required
- Lead teams to translate end-user feedback into corrective action plans and recommend technical changes
- Develop and implement approved system proposed changes to ensure end-user needs continue to be met
- Conduct ESOH risk assessments and maintain oversight of critical safety item supply chain management
- Conduct analysis to identify and mitigate potential obsolescence impacts (i.e., Diminishing Manufacturing Sources and Material Shortages (DMSMS))
- Support implementation of follow-on development efforts in response to formal decisions to extend the weapon system's service life (SLEP) or to initiate a major modification (may be treated as a stand-alone acquisition program)
- Update and maintain system certifications and external SoS interfaces

Inputs

Table 4.2.7.T1 summarizes the primary inputs associated with this sustainment part of the life cycle.

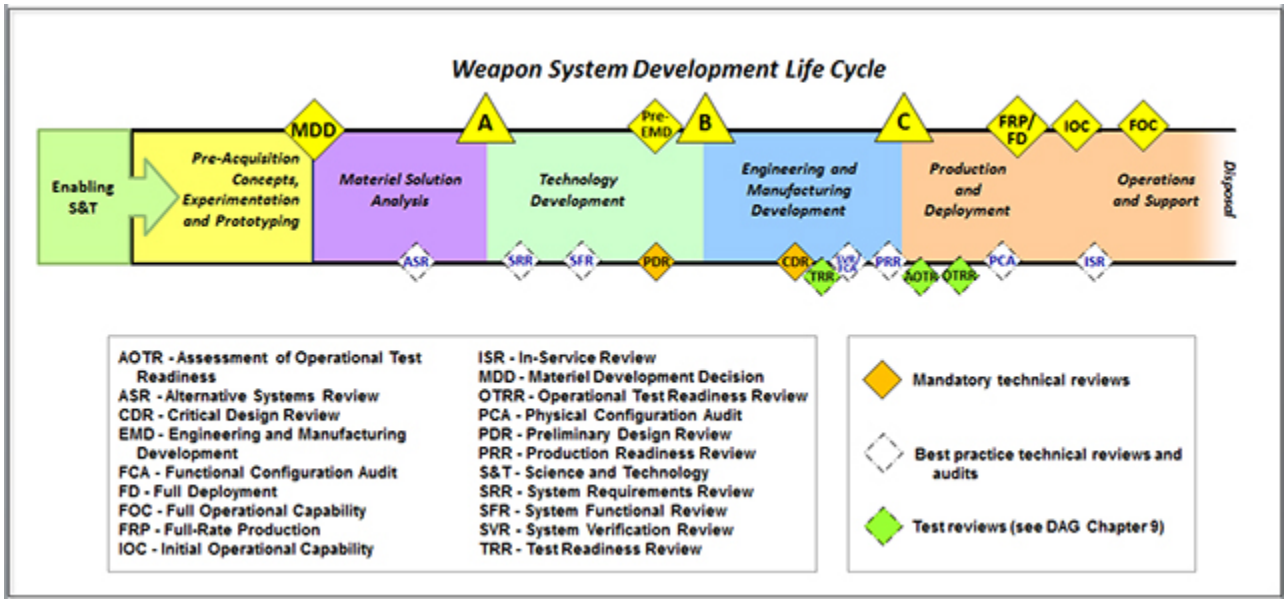
Table 4.2.7.T1. Inputs Associated with O&S Phase

Inputs for O&S Phase
Acquisition Decision Memoranda (ADMs) associated with Milestone C and Full Deployment (FD) decision review (DR) • ADMs may contain additional direction • O&S may start as early as Milestone C (e.g., software) and overlap P&D phase • FD DR would involve O&S
Trade study results • P&D phase trade studies may support manufacturing or other system modifications (technology insertion, technology refresh, etc.)
ESOH analyses (updated) • ESOH analyses continue during O&S to include hazard analysis and supporting NEPA/EO 12114 compliance for modifications and disposal
Risk assessment
Interdependencies / interfaces / memoranda of agreement (MOAs)
System performance specification
Field failures
Other technical information, such as models and simulations generated during the P&D phase
LCSP • PDUSD(AT&L) memorandum, "Document Streamlining - Life-Cycle Sustainment Plan (LCSP)," September 14, 201 • See DAG Chapter 5 Life-Cycle Logistics
Test and Evaluation Master Plan (TEMP) • DOT&E memorandum, "DOT&E TEMP Guidebook," February 27, 2012 • See DAG Chapter 9 Test and Evaluation
Request for Proposal (RFP) for SE support to O&S activities
Program Protection Plan (PPP) • PDUSD(AT&L) memorandum, "Document Streamlining - Program Protection Plan (PPP)," July 18, 2011 • See DAG Chapter 13 Program Protection
Other analyses • End-user feedback and trouble reports • Other prior analytic, prototyping, and/or technology demonstration efforts conducted by the science and technology (S&T) community • Technology insertion/transition can occur at any point in the life cycle

Activities

The O&S phase overlaps with the Production and Deployment phase, since O&S activities begin when the first system is fielded. O&S ends when a system is demilitarized and disposed of. Figure 4.2.7.F1 provides the end-to-end perspective and the integration of SE technical reviews and audits across the acquisition life cycle.

Figure 4.2.7.F1. Weapon System Development Life Cycle



SE activities should be integrated with O&S phase-specific test and evaluation and logistics and sustainment activities identified in DAG Chapter 9 Test and Evaluation and Chapter 5 Life-Cycle Logistics, respectively. The O&S activities in which the Systems Engineer should participate include:

- Determine root cause of problems, identify corrective actions, and manage to completion
- Address problem/failure reports through the use of a comprehensive data collection approach such as a Failure Reporting, Analysis and Corrective Action System (FRACAS)
- Process and analyze mission data
- Manage preplanned product improvements (P3I)
- Develop and implement technology refresh schedules
- Conduct technology insertion efforts as needed to maintain or improve system performance
- Update system safety assessments
- Perform engineering analysis to investigate the impact of DMSMS issues
- Work with vendors and the general technical community to determine opportunities for technology incursion to increase reliability and affordability

The disposal activities in which the Systems Engineer should participate include:

- Support demilitarizing and disposing of the system; in accordance with all legal and regulatory requirements and policy relating to safety (including explosives safety), security, and the environment
- Document lessons learned
- Archive data

The technical review conducted in O&S is the In-Service Review (ISR) (see DAG section 4.2.17. In-Service Review). ISRs are typically used to track, monitor, and assess system performance from the time an Initial Operational Capability (IOC) is reached until retirement or disposal of the system. They are often used to prioritize system modifications due to deficiencies or integration of additional capability, or to respond to external needs associated with SoS implementations.

Outputs and Products

The technical outputs and products identified in Table 4.2.7.T2 are necessary to support SE processes to sustain the system, including modifications. Technical outputs associated with technical reviews in this phase are addressed later in this chapter.

Table 4.2.7.T2. Technical Outputs Associated with O&S Phase

Technical Outputs from O&S Phase
Safe and reliable system that meets operational needs
Trade study results • O&S phase trade studies support system modifications and/or disposal efforts
Assessment of technical risk
Interdependencies / interfaces / memoranda of agreement (MOAs)
In-service performance and failure data
Value engineering results, as appropriate • See DAG section 4.3.19.3. Value Engineering
Engineering Change Proposal (ECP) packages

4.2.8. Technical Reviews and Audits Overview

4.2.8. Technical Reviews and Audits Overview

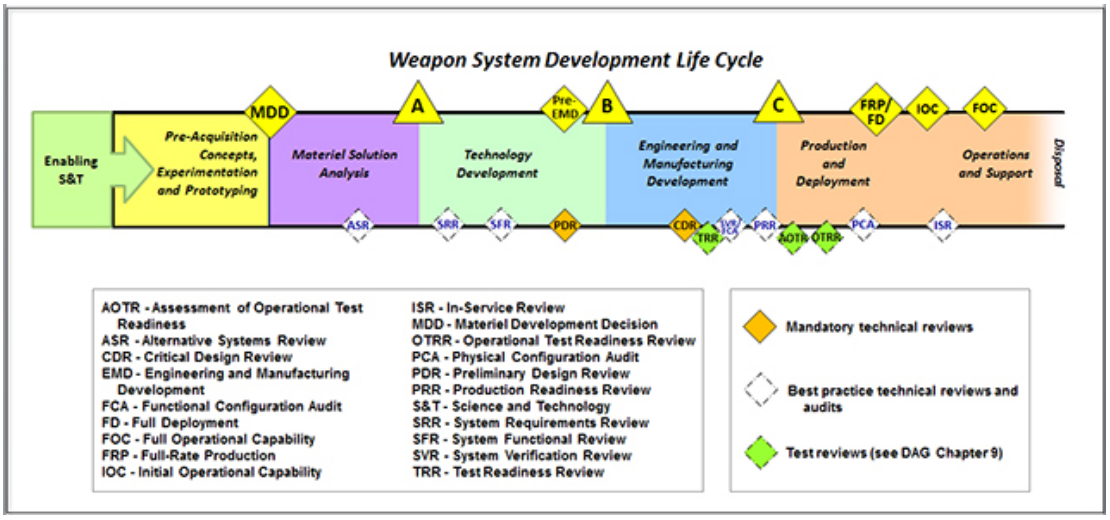
For DoD weapon systems development, a properly tailored series of technical reviews and audits provide key points throughout the life cycle to evaluate significant achievements and assess technical maturity and risk. DoDI 5000.02, Enclosure 4 presents the statutory, regulatory, and milestone requirements for acquisition programs. Properly align the technical reviews to support knowledge-based milestone decisions to streamline the acquisition life cycle and save precious taxpayer dollars. As a companion to DoDI 5000.02, see the OUSD(AT&L) memorandum, "Expected Business Practice: Document Streamlining - Program Strategies and Systems Engineering Plan" dated April 20, 2011.

Technical reviews and audits allow the Program Manager and Systems Engineer to jointly define and control the program's technical effort by establishing the success criteria for each review and audit. A well-defined program facilitates effective monitoring and control through increasingly mature points (see Technical Maturity Point table in DAG section 4.2.1. Life-Cycle Expectations).

Technical reviews of program progress should be event driven and conducted when the system under development meets the review entrance criteria as documented in the SEP. Systems engineering (SE) is an event-driven process based on successful completion of key events as opposed to arbitrary calendar dates. As such, the SEP should discuss the timing of events in relation to other SE and program events. While the initial SEP and Integrated Master Schedule have the expected occurrence in the time of various milestones (such as overall system CDR), the plan should accommodate and be updated to reflect changes to the actual timing of SE activities, reviews, and decisions.

Figure 4.2.8.F1 provides the end-to-end perspective and the integration of SE technical reviews and audits across the acquisition life cycle.

Figure 4.2.8.F1. Weapon System Development Life Cycle



Properly structured, technical reviews and audits support the Defense Acquisition System by:

- Providing a disciplined sequence of activities to define, assess, and control the maturity of the system's design and technical baseline, reducing risk over time
- Facilitating an accurate technical assessment of the system's ability to satisfy operational requirements established in capability requirements documents
- Providing a framework for interaction with the Joint Capabilities Integration and Development System (JCIDS) and Planning, Programming, Budgeting, and Execution (PPBE) processes
- Providing a technical assessment and assurance that the end product fulfills the design and process requirements

Successful development of a complex weapon system requires a knowledge-based approach. Increasing levels of knowledge are a natural consequence of design maturation; however, successful programs establish a deliberate acquisition approach whereby major investment decision points are supported by requisite levels of knowledge. The Government Accountability Office's (GAO) study on Assessments of Selected Weapons Programs (GAO-12-400SP) provides quantitative evidence to affirm this best practice.

Figure 4.2.8.F1 illustrates the notional sequence of technical reviews and audits. It also provides typical timing associated with the acquisition phases. Technical reviews should occur when the requisite knowledge is expected and required. The guidance provided in DAG sections 4.2.9. through 4.2.17. defines the entrance and exit criteria for the level of maturity expected at each technical review and audit. OSD established the expected reviews and audits for each acquisition phase in the outline for the Systems Engineering Plan (SEP). These policy and guidance documents provide a starting point for the Program Manager and Systems Engineer to develop the program's unique set of technical reviews and audits. Tailoring is expected to best suit the program objectives (see DAG section 4.1. Introduction). The SEP captures the output of this tailoring and is reviewed and approved to solidify the program plan.

Programs that tailor the timing and scope of these technical reviews and audits to satisfy program objectives increase the probability of successfully delivering required capability to the warfighter. Technical reviews provide the forum to frame important issues and define options necessary to balance risk in support of continued development.

The technical baseline (including the functional, allocated and product baselines) established at the conclusion of certain technical reviews inform all other program activity. Accurate baselines and disciplined reviews serve to integrate and synchronize the system as it matures, which facilitates more effective milestone decisions and ultimately provides better warfighting capability for less money. The technical baseline provides an accurate and controlled basis for:

- Managing change
- Cost estimates, which inform the PPBE process and ultimately the Acquisition Program Baseline (APB)
- Program technical plans and schedules, which also inform the APB
- Contracting activity
- Test and Evaluation efforts
- Risk analysis and risk balancing
- Reports to acquisition executives and Congress

The Program Manager and the Systems Engineer need to keep in mind that technical reviews and audits provide visibility into the quality and completeness of the developer's work products. These requirements should be captured in the contract specifications or Statement of Work. The program office should consider delivering the SEP with the Request for Proposal (RFP) and having it captured in the contractor's SE Management Plan (SEMP); this best practice also should include delineating entrance criteria and associated design data requirements needed to

support the reviews. The configuration and technical data management plans should clearly define the audit requirements.

For complex systems, reviews and audits may be conducted for one or more system elements depending on the interdependencies involved. These incremental system element-level reviews lead to an overall system-level review or audit (e.g., PDR, CDR, or PRR). After all incremental reviews are complete, an overall summary review is conducted to provide an integrated system analysis and capability assessment that could not be conducted by a single incremental review. Each incremental review should complete a functional or physical area of design. This completed area of design may need to be reopened if other system elements drive additional changes in this area. If the schedule is being preserved through parallel design and build decisions, any system deficiency that leads to reopening design may result in rework and possible material scrap.

Test readiness reviews (TRR) are used to assess a contractor's readiness for testing configuration items, including hardware and software. They typically involve a review of earlier or lower-level test products and test results from completed tests and a look forward to verify the test resources, test cases, test scenarios, test scripts, environment, and test data have been prepared for the next test activity. TRRs typically occur in the EMD and P&D phase of a program.

Roles and Responsibilities

For each technical review, a technical review chair is identified and is responsible for evaluating products, determining the criteria are met, and determining that actions items are closed. The Service chooses the technical review chair who could be the Program Manager, Systems Engineer, or independent subject matter expert selected according to the Service's guidance. This guidance may identify roles and responsibilities associated with technical reviews and audits. It also may specify the types of design artifacts required for various technical reviews. In the absence of additional guidance, each program should develop and document its tailored design review plan in the SEP.

The following notional duties and responsibilities associated with the Program Manager and Systems Engineer should be considered in the absence of specific Service or lower level (e.g., System Command or Program Executive Officer) guidance:

The Program Manager is responsible for:

- Co-developing with the Systems Engineer the technical objectives of the program that guide the technical reviews and audits
- Co-developing with the Systems Engineer the earned value credit derived from the review
- Approving, funding, and staffing the planned technical reviews and audits; documenting this plan in the SEP and applicable contract documents
- Ensuring the plan includes independent subject matter experts to participate in each review (maintaining objectivity during these reviews with respect to satisfying the pre-

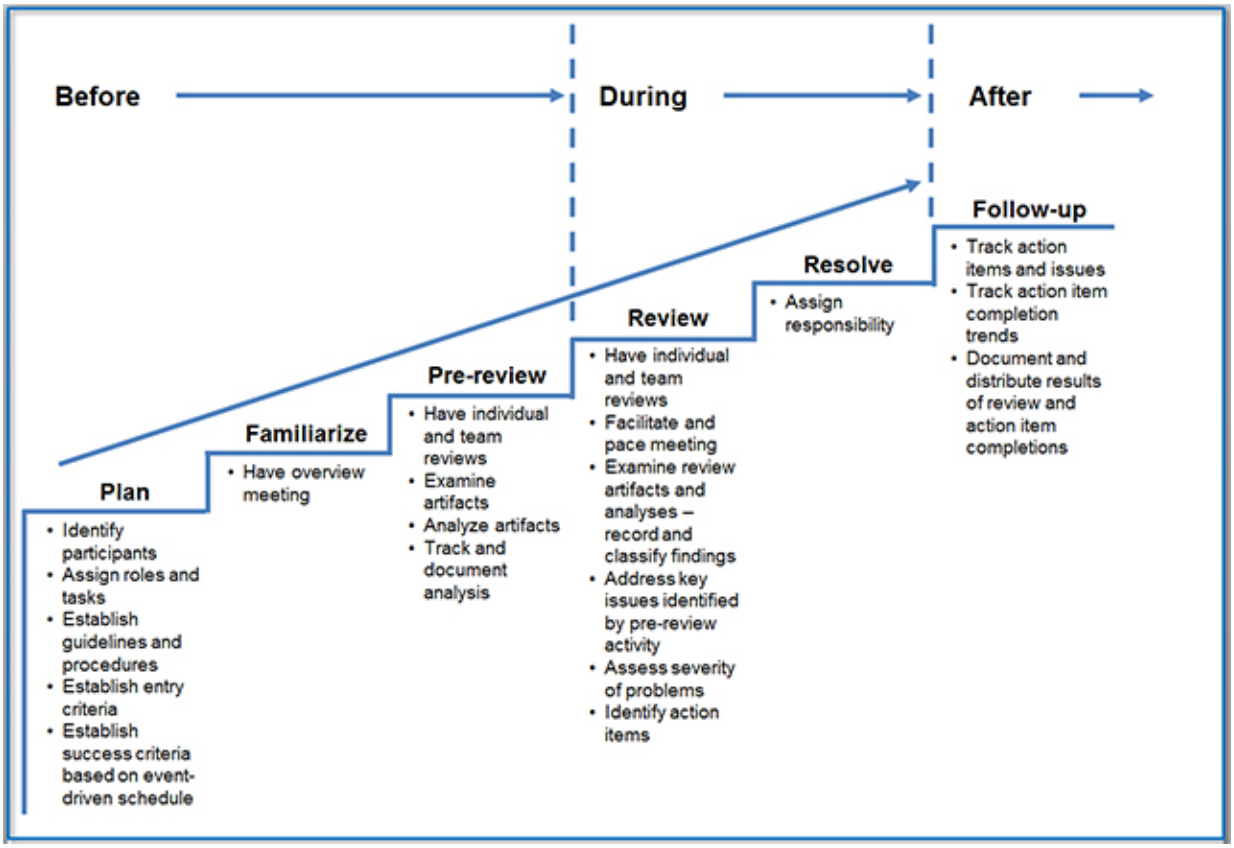
established review criteria)

- Ensuring the plan provides timely and sufficient data to satisfy the statutory and regulatory requirements of DoDI 5000.02
- Controlling the configuration of each baseline and convening configuration steering boards when user requirement changes are warranted. This can lead to an unscheduled gateway into the Functional Capabilities Board (FCB) and JCIDS process not identified in Figure 4.2.8.F1 above.

The Systems Engineer is responsible for:

- Co-developing with the Program Manager the technical objectives of the program that guide the technical reviews and audits
- Developing and documenting the technical review and audit plan in the SEP, carefully tailoring each event to satisfy program objectives and SEP outline guidance associated with the minimum technical reviews and audits. Technical review checklists are available on the DASD(SE) website.
- Ensuring the plan is event based with pre-established review criteria for each event, informed by the knowledge point objectives in Table 4.2.1.T1
- Identifying the resources required to support the plan, paying particular attention to the importance of the integrating activity leading up to the official review and audit. See Figure 4.2.8.F2.
- Ensuring technical reviews and audits are incorporated into the IMP and IMS
- Coordinating with Chief Development Tester to provide at each technical review: reliability growth progress to plan/assessments, DT&E activities to-date, planned activities, assessments to-date, and risk areas
- Ensuring a status of applicable design considerations are provided at each technical review
- Establishing technical reviews and audits and their review criteria in the applicable contract documents (e.g., Statement of Work, IMP)
- Monitoring and controlling execution of the established plans
- Coordinating with the appointed technical review chairperson on the technical review plans and supporting execution of the technical reviews
- Assigning responsibilities for closure actions and recommend to the chairperson and Program Manager when a system technical review should be considered complete, see Figure 4.2.8.F2

Figure 4.2.8.F2. Technical Review Process



The Program Manager and Systems Engineer should identify key stakeholders who have an interest or role in the review, which may include:

- Technical review chairperson
- Program Executive Office
- Contracting Officer
- Defense Contract Management Agency (DCMA) and Defense Contract Audit Agency (DCAA)
- Product Support Manager
- Product Improvement Manager/Requirements Officer
- End-user Community
- Chief Developmental Tester
- Interdependent Acquisition Programs
- Business Financial Manager
- Deputy Assistant Secretary of Defense for Systems Engineering (DASD(SE))
- Service Technical Leadership such as chief engineers
- Independent Subject Matter Experts

Review Criteria

Specific review criteria are provided in each technical review and audit section below. These criteria should be achieved and all action items closed before a technical review is considered complete. The Systems Engineer may want to consider the technical review-specific checklists available at DAU's website as a resource.

Contract incentives are frequently tied to completion of technical reviews. The developer may have a strong incentive to call the review complete as soon as possible. The review chairperson and Systems Engineer should exercise best judgment in an objective, informed manner to ensure the reviews are not prematurely declared complete.

4.2.9. Alternative Systems Review

4.2.9. Alternative Systems Review

The Alternative Systems Review (ASR) is held to support a dialogue between the end user and acquisition community and leads to a draft performance specification for the preferred materiel solution. The ASR typically occurs during the Materiel Solution Analysis (MSA) phase, after completion of the Analysis of Alternatives (AoA) and before Milestone A. It focuses technical efforts on requirements analysis.

The ASR should evaluate whether there is sufficient understanding of the technical maturity, feasibility, and risk of the preferred materiel solution, in terms of addressing the operational capability needs in the Initial Capabilities Document (ICD) and meeting affordability, technology, and operational effectiveness and suitability goals.

The ASR helps the Program Manager and Systems Engineer ensure that further engineering and technical analysis needed to draft the system performance specification is consistent with customer needs.

CJCSI 3170.01 calls for a Functional Capabilities Board (FCB) review prior to Milestone A. This FCB review should ensure compatibility between the operational capability needs in the ICD and the maturity, feasibility, and risks of the preferred materiel solution.

Roles and Responsibilities

The unique Program Manager responsibilities associated with an ASR include:

- Approve, fund, and staff the ASR

The unique Systems Engineer responsibilities associated with an ASR include:

- Ensure adequate plans are in place to complete the necessary technical activities for the ASR
- Ensure results of all technical trade studies are captured in documents that are carried

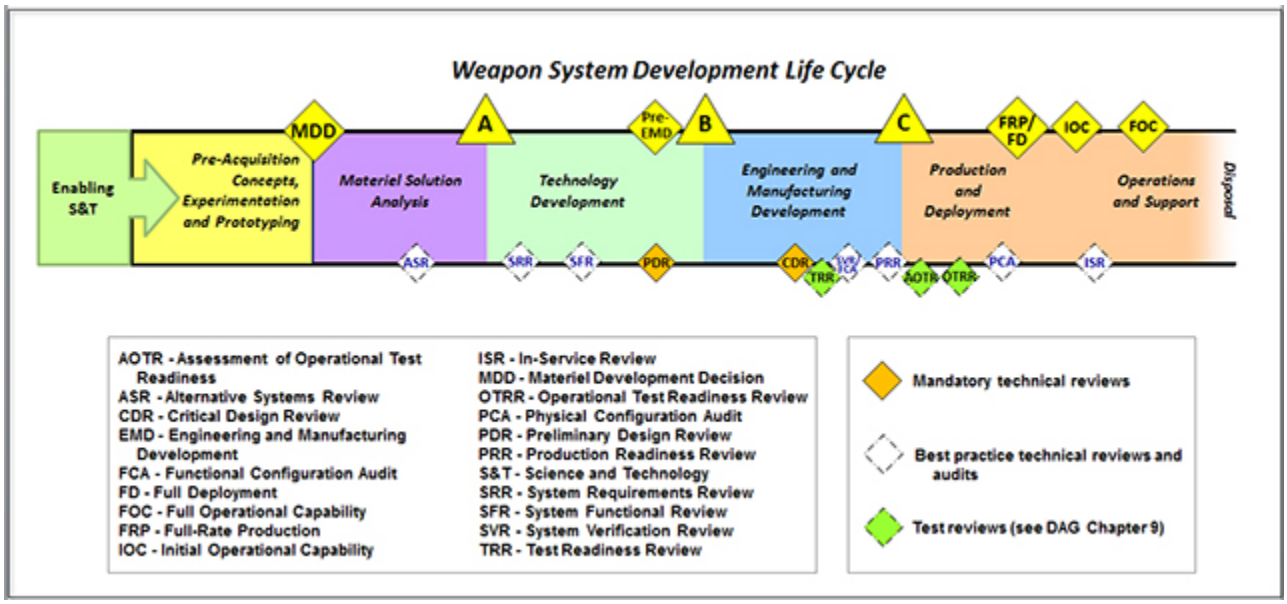
through to the next phase

- Ensure technical risk items are identified and analyzed, and appropriate mitigation plans are in place. This activity should include, for example, the identification of critical technologies and identification of key interfaces with supporting or enabling systems

Inputs and Review Criteria

The ASR typically occurs after the AoA is complete and after a preferred materiel solution is selected by the lead Service or Component but before the FCB review. Figure 4.2.9.F1 provides the end-to-end perspective and the integration of SE technical reviews and audits across the acquisition life cycle.

Figure 4.2.9.F1. Weapon System Development Life Cycle



This timing allows the focus of the ASR to be on the preferred materiel solution rather than on all the alternatives and allows for some post-AoA technical analysis to be completed and inform the FCB deliberations.

- The AoA results are an input to the ASR. The AoA should have evaluated a number of candidate materiel solutions and identified those alternatives that can meet the user requirements within the remaining trade space (including cost and affordability constraints).
- After the AoA is complete, the operational requirements community and the acquisition community collaboratively identify one or more preferred materiel solution(s) with the potential to be affordable, operationally effective and suitable, sustainable, and technically and technologically achievable (i.e., able to provide a timely solution to the stated operational capability need at an acceptable level of risk). This preferred materiel solution is also an input to the ASR.
- The draft concept of operations (CONOPS) should be available as an input to the ASR. It

should have been available for use in the AoA and can then be used to support development of missions and operational scenarios used to evaluate the preferred materiel solution.

Table 4.2.9.T1 defines the suggested ASR artifacts and associated review criteria. The review should not begin until these criteria are considered met. This is a best practice review.

Table 4.2.9.T1. ASR Products and Criteria

Product	ASR Criteria
Refined Joint Requirements	• Joint context and initial CONOPS updated to reflect current user position about capability gap(s), supported missions, interfacing/enabling systems in the operational architecture; overall system of systems (SoS) context • Required related solutions and supporting references (ICD and CDDs) identified • Joint refined thresholds and objectives initially stated as broad measures of effectiveness and suitability (e.g., KPPs, KSAs, need date)
Initial Architecture for the Preferred Materiel Solution(s)	• High-level description of the preferred materiel solution(s) is available and sufficiently detailed and understood to enable further technical analysis in preparation for Milestone A • SoS interfaces and external dependencies are adequately defined
System Performance Specification	• Clear understanding of the system requirements consistent with the ICD and draft CDD (if available) • System requirements are sufficiently understood to enable system functional definition • Draft system performance specification has sufficiently conservative requirements to allow for design trade space • Relationship between draft system specification and competitive prototyping objectives is established
Preferred Materiel Solution(s) Documentation	• Comprehensive rationale is available for the preferred materiel solution(s), based on the AoA • Key assumptions and constraints associated with preferred materiel solution(s) are identified and support the conclusion that this solution can reasonably be expected to satisfy the ICD (or draft CDD if available) in terms of technical, operational, risk, and schedule/cost (affordability) criteria • Results of trade studies/technical demonstrations for concept risk reduction, if available • Initial producibility assessments of solution concepts
Risk Assessment	• Technical risks are identified, and mitigation plans are in development • Initial hazard analysis/system safety analysis for preferred solution(s) complete

Outputs and Products

The Technical Review Chair determines when the review is complete. ASR technical outputs should include, but not be limited to, the following products, including supporting rationale and

trade study results:

- Refined description of the preferred materiel solution to support further development
- Informed advice to the user-developed draft Capability Development Document (CDD) required at Milestone A

4.2.10. System Requirements Review

4.2.10. System Requirements Review

The System Requirements Review (SRR) is a multi-disciplined technical review to ensure that the developer is ready to proceed with the initial system design. This review assesses whether the system requirements as captured in the system performance specification:

- Are consistent with the preferred materiel solution (including its support concept) from the Materiel Solution Analysis (MSA) phase
- Are consistent with available technologies resulting from the prototyping efforts
- Adequately consider the maturity of interdependent systems

All system requirements and performance requirements derived from the Initial Capabilities Document (ICD) or draft Capability Development Document (CDD) should be defined and consistent with cost, schedule, risk, and other system constraints; and with end user expectations. Also important to this review is a mutual understanding (between the program office and the developer) of the technical risk inherent in the system performance specification.

For Major Defense Acquisition Programs (MDAPs), the PDUSD(AT&L) memorandum, "Improving Milestone Process Effectiveness" requires a Milestone A review before approving release of the final Request for Proposal (RFP) for the Technology Development (TD) phase; therefore, it is suggested that the program office perform a review similar to an SRR to assess readiness and risks of the technical content of the draft RFP(s) prior to Milestone A. This program office review most likely occurs after the Functional Capabilities Board (FCB) review of the AoA and other analytic results.

If the program's Technology Development Strategy (TDS) includes competing contractual efforts during the TD phase, an SRR should be held with each participating developer to ensure the requirements are thoroughly and properly understood. This review also ensures that system of systems (SoS) requirements, in the form of logical and physical interfaces and desired performance outcomes, have been levied on the system to be procured and are consistent with the ICD and/or draft CDD. These requirements are documented in the system performance specification and managed through external communication and technical interfaces in accordance with the Systems Engineering Plan (SEP).

Roles and Responsibilities

The unique Program Manager responsibilities associated with an SRR include:

- Approve, fund, and staff the SRR as planned in the SEP developed by the Systems Engineer
- Manage and approve changes to the system performance specification
- Establish the plan to SFR in applicable contract documents including the SE Master Plan, Integrated Master Schedule (IMS), and Integrated Master Plan (IMP)
- Ensure the plan includes independent subject matter experts to participate in each review

The unique Systems Engineer responsibilities associated with an SRR include:

- Ensure all performance requirements, both explicit and derived, are defined and traceable (both directions) between requirements in the draft CDD including Key Performance Parameters (KPPs), Key System Attributes (KSAs), other system attributes, and the system performance specification (see CJCSI 3170.01 JCIDS)
- Ensure verification methods are identified for all system requirements
- Ensure risk items associated with system requirements are identified and analyzed, and mitigation plans are in place
- Ensure adequate plans are in place to complete the technical activities to proceed from SRR to the System Functional Review (SFR)
- Ensure plans to proceed to SFR allow for contingencies

Inputs and Review Criteria

Figure 4.2.10.F1 provides the end-to-end perspective and the integration of SE technical reviews and audits across the acquisition life cycle. The SRR criteria are developed to best support the program's technical scope and risk and are documented in the program's SEP at Milestone A.

Figure 4.2.10.F1. Weapon System Development Life Cycle

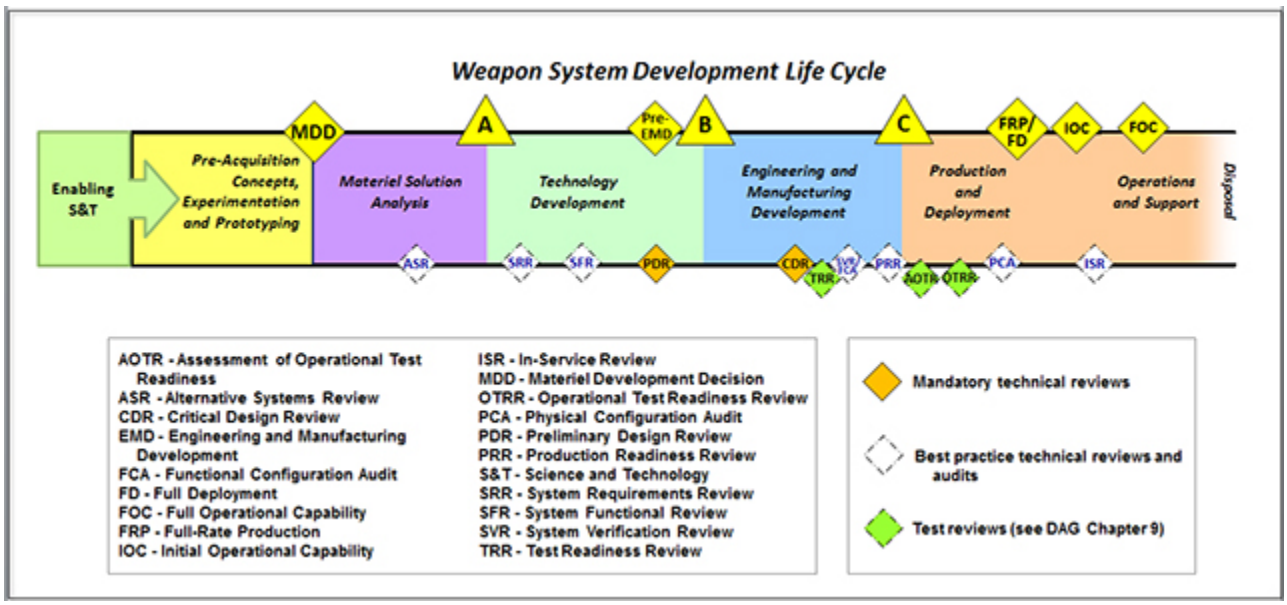


Table 4.2.10.T1 defines the suggested SRR products and associated review criteria. The review

should not begin until these criteria are established, evidence has been received to support a case for success, and any prior technical review is completed and its action items closed. This is also an opportunity to assess whether technical requirements from all acquisition documentation (e.g., Program Protection Plan (PPP), Test and Evaluation Master Plan (TEMP), Reliability, Availability, Maintainability, and Cost Rationale (RAM-C) Report) are flowed to specifications. If the program's TDS includes competing contractual efforts, an SRR should be held with each developer. A risk assessment tool for SRR preparation is the DoD SRR Checklist. This is a best practice review.

Table 4.2.10.T1. SRR Products and Criteria

Product	SRR Criteria
Cost Estimate	• Preliminary Cost Analysis Requirements Description (CARD) is consistent with the approved system performance specification • Preliminary software development estimates established with effort, schedule, and cost analysis • Updated cost estimate fits within the existing budget
Risk Assessment	• Technical risks are identified, and mitigation plans are in place • Risk Management Plan (RMP) is complete and adequate
System Performance Specification	• Contractor clearly demonstrates an understanding of the system requirements consistent with the ICD and draft CDD • System requirements are sufficiently detailed and understood to enable system functional definition and functional decomposition • System requirements are assessed to be verifiable (see Chief Developmental Tester in DAG Chapter 9 Test and Evaluation) • Requirements can be met given the technology maturation achieved and evidence from competitive prototyping • External interfaces to the system have been documented in interface control documents • SoS technical interfaces are adequately defined, including interdependences associated with schedule, test, and configuration changes • Preliminary identification of all software components (tactical, support, deliverable, non-deliverable, etc.) are completed • Human Systems Integration (HSI) and sustainment requirements have been reviewed and included in the overall system design (see DAG section 4.3.18.10 and DAG Chapter 6 Human Systems Integration) • Contractor has adequately expanded the system specification to reflect tailored, derived, and correlated design requirements • Bidirectional requirements traceability between the draft CDD, the Statement of Work (SOW), and the System Specification has been documented • System performance specification is approved, including stakeholder concurrence, with sufficiently conservative requirements to allow for design trade space

Product	SRR Criteria
Technical Plans	• Contractors Systems Engineering Management Plan (SEMP) is complete and adequate • Cost and critical path drivers have been identified • The program schedule is executable with an acceptable level of technical and cost risk • Adequate processes and metrics are in place for the program to succeed • SE is properly staffed • Program is executable within the existing budget • Software functionality in the system specification is consistent with the software sizing estimates and the resource-loaded schedule • Programming languages and architectures, security requirements, and operational and support concepts have been identified • Hazards have been reviewed and mitigating courses of action have been allocated within the overall system design • Key technology elements have been identified, readiness assessed, and maturation plans developed • Software development strategy is complete and adequate • Program technical risks are adequately identified and documented such that there is a clear understanding regarding the contractor's ability to meet the specification requirements • Draft verification methodologies have been adequately defined for each specification requirement • Certifying agencies have been identified and certification requirements are understood • Draft test plans have been developed in support of the TD phase (See Chief Developmental Tester in DAG Chapter 9 Test and Evaluation) • Government and contractor configuration management (CM) strategies are complete and adequate • The Modeling and Simulation (M&S) Plan for life-cycle support (including life-cycle costs / total ownership costs (LCC/TOC), training devices, tactics, air vehicle, mission system etc.) is complete and adequate to support system design and operation • The manufacturing and production strategy is complete and adequate • Integrated Master Schedule (IMS) adequately identifies the critical path and is resourced at reasonable levels, based on realistic performance/efficiency expectations • Unique work requirements for competitive prototyping have been identified • Product support plan and sustainment concepts have been defined with the corresponding metrics

Output and Products

The Technical Review Chair determines when the review is complete. Once the products have been reviewed and approved in SRR, they provide a sound technical basis for proceeding with

system functional definition and preliminary design.

4.2.11. System Functional Review

4.2.11. System Functional Review

The System Functional Review (SFR) is held to evaluate whether the system functional baseline satisfies the end-user requirements and capability needs and whether functional requirements and verification methods support achievement of performance requirements. At completion of the SFR, the system's functional baseline is normally taken under configuration control.

The functional baseline describes the system's performance (functional, interoperability, and interface characteristics) and the verification required to demonstrate the achievement of those specified characteristics. It is directly traceable to the operational requirements contained in the Initial Capabilities Document (ICD) and draft Capability Development Document (CDD). The Program Manager establishes Government control of the functional baseline at the SFR and verifies it through Functional Configuration Audits (FCA) leading up to the system level FCA or the System Verification Review (SVR). For additional information, see DAG section 4.3.7. Configuration Management Process.

A successful SFR, which typically occurs during the Technology Development (TD) phase, reduces the risk of continuing the technical effort toward the Preliminary Design Review (PDR). The SFR is used to:

- Assess whether a balanced definition of the system's major elements has been developed, including their functionality and performance requirements
- Assess whether the system functional baseline is technically achievable with regard to cost, schedule, and performance
- Confirm that the system performance specification (typically put on contract) is realistic and provides a sound technical foundation for preliminary design
- Establish functional baseline and verification criteria to be used during FCA

Roles and Responsibilities

The unique Program Manager responsibilities associated with an SFR include:

- Approve, fund, and staff the SFR as planned in the Systems Engineering Plan (SEP) developed by the Systems Engineer
- Manage and approve changes to the system performance specification
- Establish the plan to PDR in applicable contract documents including the SE Management Plan (SEMP), Integrated Master Schedule (IMS), and Integrated Master Plan (IMP)
- Ensure the plan includes independent subject matter experts to participate in each review
- Control the configuration of the Government-controlled subset of the functional baseline
- Chair the configuration control board (CCB) for the system performance specification

This document is an accurate representation of the content posted on the DAG website for this Chapter, as of the date of production listed on the cover. Please refer to the DAG website for the most up to date guidance at https://dag.dau.mil

and other documentation used to control the system functional baseline

The unique Systems Engineer responsibilities associated with an SFR include:

- Ensure adequate plans are in place to complete the necessary technical activities to proceed from SFR to PDR
- Ensure plans to proceed to PDR allow for contingencies
- Ensure all performance requirements, both explicit and derived, are defined and traceable (both directions) between requirements in the draft CDD to include Key Performance Parameters (KPPs), Key System Attributes (KSAs), other system attributes, and the system performance specification (see CJCSI 3170.01 JCIDS)
- Ensure verification methods are identified for all requirements
- Ensure risk items associated with functional requirements are identified and analyzed, and mitigation plans are in place

Inputs and Review Criteria

The SFR criteria are developed to best support the program's technical scope and risk and are documented in the program's SEP at Milestone A. Figure 4.2.11.F1 provides the end-to-end perspective and the integration of SE technical reviews and audits across the acquisition life cycle.

Figure 4.2.11.F1. Weapon System Development Life Cycle

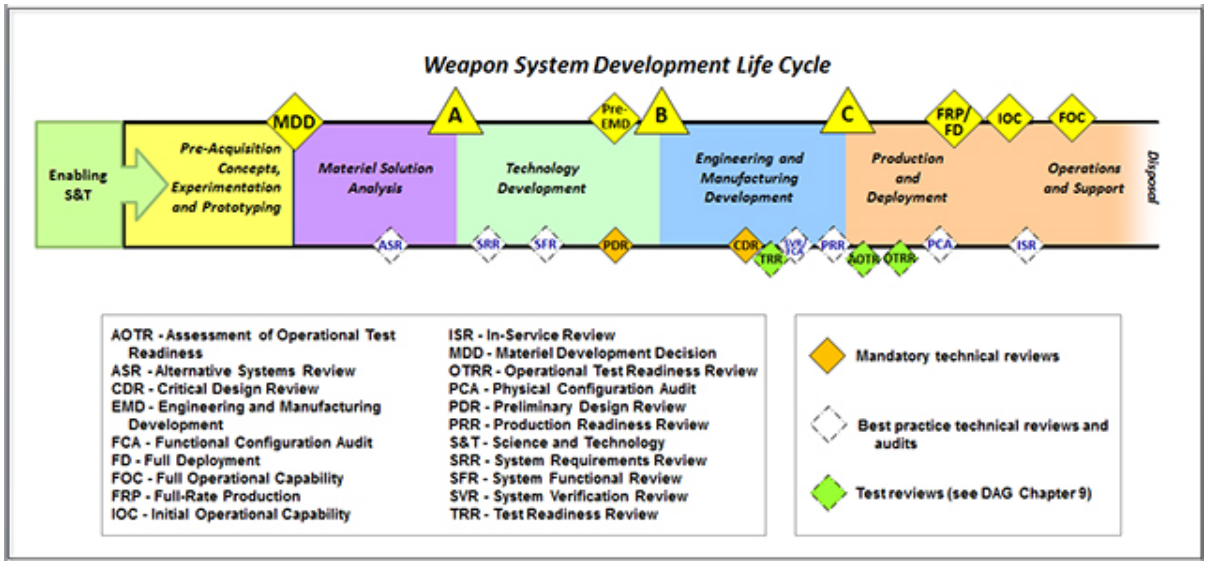


Table 4.2.11.T1 defines the suggested SFR products and associated review criteria. The review should not begin until these criteria are considered met and any prior technical review is completed and its action items closed. If the program's Technology Development Strategy (TDS) includes competing contractual efforts, an SFR should be held with each participating developer. A readiness assessment tool for SFR preparation is the DoD SFR Checklist. This is a best practice review.

Table 4.2.11.T1. SFR Products and Criteria

Product	SFR Criteria
System Functional Baseline Documentation	• Understood and assessed to be achievable within cost and schedule constraints • Established functional baseline by mapping requirements to hardware, software, and human elements of the system • Documented performance requirements traced to (draft) CDD requirements and reflecting clear linkage to the system of system (SoS) context(s) (including use in multiple operational environments) • Documented performance requirements reflect design considerations • Documented verification requirements, including testing, for FCA/SVR
Major System Element Definition	• Documented preliminary allocated requirements optimized through analyses (including functional analysis and sensitivity analysis), trade studies, and risk assessments
Risk Assessment	• Identified and documented risks, including ESOH mitigation measure requirements, at levels that warrant continued engineering development
Technical Plans	• Established detailed plan/schedule, sufficiently resourced to continue design and development

Outputs and Products

The Technical Review Chair determines when the review is complete. Once the products have been reviewed and approved in SFR, they provide a sound technical basis for proceeding into preliminary design.

4.2.12. Preliminary Design Review

4.2.12. Preliminary Design Review

The Preliminary Design Review (PDR) ensures the preliminary design and basic system architecture are complete, and that there is technical confidence the capability need can be satisfied within cost and schedule goals. The PDR provides the acquisition community, end user, and other stakeholders with an opportunity to understand the trade studies conducted during the preliminary design, and thus confirm that design decisions are consistent with the user's performance and schedule needs prior to formal validation of the Capability Development Document (CDD). The PDR also establishes the system's allocated baseline.

The allocated baseline describes the functional and interface characteristics for all system elements (allocated and derived from the higher-level product structure hierarchy) and the verification required to demonstrate achievement of those specified characteristics. The allocated baseline for each lower-level system element (hardware and software) is usually established and put under configuration control at the system element Preliminary Design Review (PDR). This process is repeated for each system element and culminates in the Program Manager establishing the complete allocated baseline at the system-level PDR. The Program Manager then verifies the allocated baseline at the Functional Configuration Audit (FCA) and/or System Verification Review (SVR) (see DAG section 4.3.7 Configuration Management Process).

The PDR is mandatory. According to DoD policy and guidance, PDR requirements include the following:

- PDR is completed prior to Milestone B for all Major Defense Acquisition Programs (MDAPs) (DTM 09-027)
- Component Acquisition Executive determines the timing of PDR relative to the Pre-Engineering and Manufacturing Development (EMD) review (DTM 09-027 and PDUSD(AT&L) memorandum, "Improving Milestone Process Effectiveness")
- PDR Report is provided to the Milestone Decision Authority (MDA) prior to the Post-PDR Assessment and should reflect any requirements trades based upon the Program Manager's assessment of cost, schedule, and performance risk (DoDI 5000.02)
- PDR Report should follow the PDR Report template which prescribes the content and responsibilities associated with all PDR completion memos

Any tailoring with respect to establishing an allocated baseline at PDR prior to Milestone B should be consistent with the approved Technology Development Strategy (TDS) and documented in the Systems Engineering Plan (SEP). In a competitive environment, each developer should establish an allocated baseline to meet the definition prescribed in the Request for Proposal (RFP) and associated system performance specification, consistent with their individual design approach. Since the functional and allocated baselines are critical to providing the Engineering and Manufacturing Development (EMD) bidders with a complete technical package, best practices would dictate that the PDR be completed prior to the pre-EMD Review, although this timing is optional under policy. The tailoring strategy may also include conduct of a delta-PDR after Milestone B if the allocated baseline has changed significantly.

A successful PDR confirms that the system's preliminary design:

- Satisfies the operational and suitability requirements of the draft CDD, as documented in the system performance specification
- Is affordable, producible, sustainable, and carries an acceptable level of risk
- Is composed of technologies demonstrated in a relevant environment that can be integrated into a system with acceptable levels of risk
- Is complete and ready for detailed design

- Provides the technical basis for the Milestone B investment decision and Acquisition Program Baseline (APB)
- Is fully captured in the specifications for each system element and all interface documentation (including system of systems (SoS) interdependencies)

In addition, the PDR represents agreement that the proposed plan to proceed to the Critical Design Review (CDR) is executable and properly resourced. The PDR establishes the allocated baseline, which is placed under formal configuration control at this point. The maximum benefit of the PDR process is realized when the allocated baseline is complete with the following attributes:

- All system-level functional performance requirements have been decomposed (or directly allocated) to the lowest level of the specification tree for all system elements uniquely identified
- All external interfaces to the system, as addressed at the System Requirements Review, have been documented in interface control documents
- All internal interfaces of the system (system element to system element) have been documented in interface control documents
- Verification requirements to demonstrate achievement of all specified allocated performance characteristics have been documented
- Design constraints have been captured and incorporated into the requirements and design

Some of the benefits realized from a PDR with the attributes identified above would be to:

- Establish the technical basis for the Cost Analysis Requirements Description (CARD), documenting all assumptions and rationale needed to support an accurate cost estimate for the APB; technically informed cost estimates enable better should cost / will cost management
- Establish the technical requirements for the detailed design, EMD contract specifications, and Statement of Work; inform the CDD
- Establish an accurate basis to quantify risk and identify opportunities
- Provide core evidence for the PDR Report
- Provide the technical foundation for section 2366b of title 10, United States Code certification required for all MDAPs

Some design decisions made at PDR may precipitate discussions with the operational requirements community because they could have an impact on the CDD. Depending upon the nature/urgency of the capability required and the current state of the technology, incremental development might be required. In this case the Sponsor should document these increments in the CDD and the Program Manager and Systems Engineer should update relevant program plans.

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Roles and Responsibilities

The Program Manager and Systems Engineer may hold incremental PDRs for lower-level system elements, culminating with a system-level PDR. The system PDR assesses the preliminary design as captured in system performance specifications for the lower-level system elements; it further ensures that documentation for the preliminary design correctly and completely captures each such specification. The Program Manager and Systems Engineer evaluate the designs and associated logistics elements to determine whether they correctly and completely implement all allocated system requirements, and whether they have maintained traceability to the CDD.

Though many Service systems commands or PEOs define the roles and responsibilities of the Program Manager and Systems Engineer, the following notional duties and responsibilities should be considered:

The Program Manager's responsibilities include the following:

- Approve, fund, and staff the system PDR as planned in the SEP developed by the Systems Engineer
- Establish the plan to CDR in applicable contract documents including the SE Management Plan (SEMP), Integrated Master Schedule (IMS), and Integrated Master Plan (IMP)
- Ensure the SEP includes independent subject matter experts to participate in each review
- Control the configuration of the Government-controlled subset of the functional and allocated baselines; convene Configuration Steering Boards when changes are warranted
- Submit the PDR Report for approval consistent with the template guidance

The Systems Engineer's responsibilities include the following:

- Develop and execute the system PDR plans with established quantifiable review criteria, carefully tailored to satisfy program objectives
- Ensure that the pre-established PDR criteria have been met
- Provide industry with an opportunity to participate in this PDR planning (pre-contract award is a best practice, where applicable)
- Support development of the PDR Report
- Ensure assessments and risks associated with all design constraints and considerations are conducted, documented, and provided (e.g., reliability and maintainability, corrosion, and Environment, Safety, and Occupational Health (ESOH) considerations)
- Determine the root cause of problems, identify corrective actions, and manage to completion
- Monitor and control the execution of the PDR closure plans
- Document the plan to CDR in the SEP and elsewhere as appropriate

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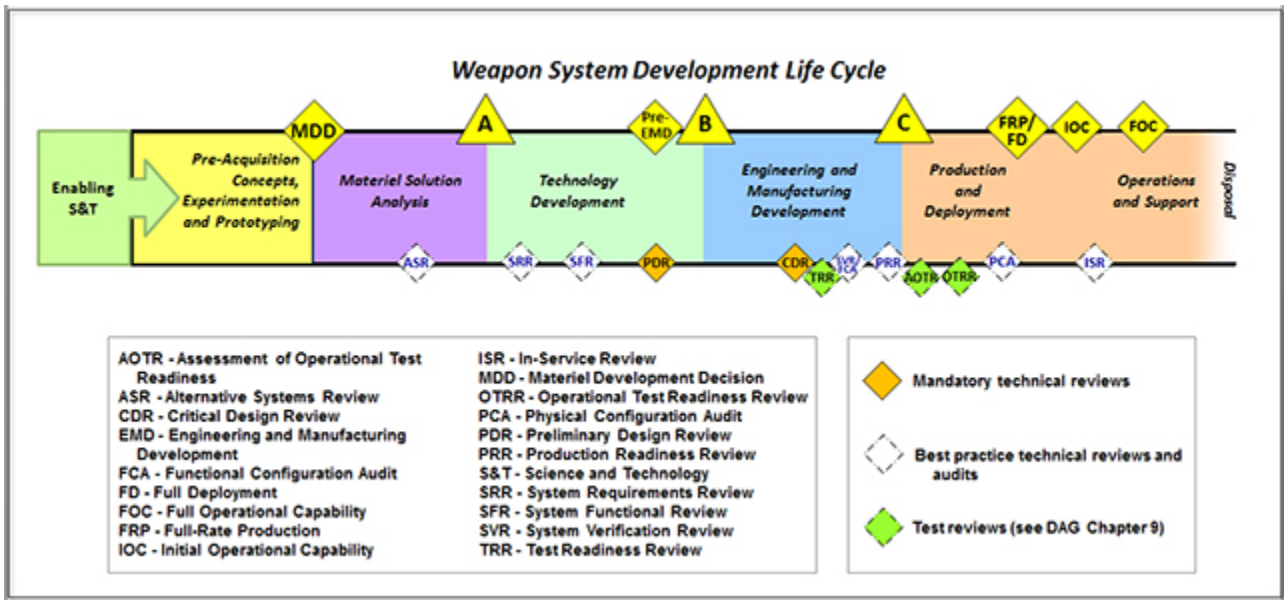
Inputs and Review Criteria

Figure 4.2.12.F1 provides the end-to-end perspective and the integration of SE technical reviews and audits across the acquisition life cycle.

Figure 4.2.12.F1. Weapon System Development Life Cycle



The PDR review criteria are developed to best support the program's technical scope and risk and are documented in the program's SEP no later than Milestone A. Table 4.2.12.T1 defines the products and associated review criteria. The system-level PDR review should not begin until these criteria are considered met and any prior technical review is complete and its action items closed. A readiness assessment tool for PDR preparation is the DoD PDR Checklist. The PDR is a mandatory technical review.

Table 4.2.12.T1. PDR Products and Criteria

Product	PDR Criteria
Cost Estimate	• System cost model has been updated, allocated to lower system element levels, and tracked against targets; production cost model constructed • Updated CARD is consistent with the proposed allocated baseline

Product	PDR Criteria
Risk Assessment	• All risk assessments and risk mitigation plans have been updated, documented, formally addressed, and implemented • Test and evaluation strategy defined in the Test and Evaluation Master Plan (TEMP) accounts for risks with a mitigation plan; necessary integration and test resources are documented within the TEMP and current availability align with the program IMS (SE coordinates with the Chief Developmental Tester in this area; refer to DAG Chapter 9 Test and Evaluation) • ESOH risks are known and being mitigated • Risks are at an acceptable level to continue with detailed design • Unique software risks identified/assessed and mitigation plans developed and implemented
System Baseline Documentation (Allocated)	• Analysis of system performance is complete and is assessed to meet requirements • Preliminary design satisfies design considerations (see DAG section 4.3.11 Requirements Analysis Process) • Producibility assessments of key technologies are complete • Preliminary system-level design is producible and assessed to be within the production budget • Assessment of the technical effort and design indicates potential for operational test and evaluation success (operationally effective and suitable) • All Critical Safety Items (CSIs) and Critical Application Items (CAIs) are identified • Functional failure mode, effects, and criticality analysis (FMECA) is completed • Estimate of system reliability and maintainability updated, based on engineering analyses, initial test results, or other sources of demonstrated reliability and maintainability • Computer system and software architecture designs have been established; all Computer Software Configuration Items (CSCIs), Computer Software Components (CSCs), and Computer Software Units (CSUs) have been defined • Software Requirements Specifications (SRSs) and Interface Requirement Specifications (IRSs), including verification plans, are complete and baselined for all CSCs and satisfy the system functional requirements • Interface control documents trace all software interface requirements to the CSCIs and CSUs • Preliminary software design has been defined and captured • All required software-related documents are baselined and delivered • System-allocated baseline documentation is sufficiently complete and correct to enable detailed design to proceed with proper configuration management
System Baseline Documentation (Functional and/or Allocated)	• Preliminary design (hardware and software), including interface descriptions, is complete and satisfies all requirements in the system functional baseline • Requirements trace between functional and allocated baselines is complete and consistent

Product	PDR Criteria
Technical Plans	• All entry criteria stated in the contract (e.g., Statement of Work (SOW), SEP, approved SEMP and system specification) have been satisfied • Integrating activities of any lower-level PDRs have occurred; identified issues are documented in action plans • Plan to CDR is accurately documented in the SEP as well as the IMP and IMS • Program is properly staffed • Adequate processes and metrics are in place for the program to succeed • Program schedule, as depicted in the updated IMS (see DAG Section 4.3.2.2. Integrated Master Plan/Integrated Master Schedule) is executable within acceptable technical and cost risks • Program is executable with the existing budget and the approved product baseline • Trade studies and system producibility assessments are under way • Majority of manufacturing processes have been defined, characterized, and documented • Logistics (sustainment) and training systems planning and documentation are sufficiently complete to support the review • Life Cycle Sustainment Plan (LCSP) is approved, including updates on program sustainment development efforts and schedules based on current budgets and firm supportability design features • LCSP includes software support requirements • Long-lead and key supply chain elements are identified • Computer system and software design/development approach have been confirmed through analyses, demonstrations, and prototyping in a relevant environment • Software increments have been defined and capabilities allocated to specific increments • Software trade studies addressing commercial-off-the-shelf, reuse, and other software-related issues are completed • Software development process is defined in a baselined Software Development Plan and reflected in the IMP and IMS • Software development schedules reflect contractor software processes and IMP/IMS software events for current and future development phases • Software development environment and test/integration labs have been established with sufficient fidelity and capacity • Software metrics have been defined and a reporting process has been implemented; metrics are being actively tracked and assessed • TEMP addresses all CSCI plans, test facilities, and test plans, including testing required to support incremental approaches and regression tests • Software development estimates (i.e., size, effort (cost), and schedule) are updated

Outputs and Products

The Technical Review Chair determines when the review is complete. Completion of the PDR establishes that:

- Technical data for the allocated baseline are complete, satisfy the system specification,

and provide a sufficient foundation for detailed design to proceed
- Risks have been balanced and are acceptable with any risk mitigation plans approved and documented in the IMS
- Feasibility, cost and schedule are determined to be within acceptable risk margins
- IMS is updated (including systems and software critical path drivers) and includes all activities required to complete CDR (assuming same developer responsible for PDR and CDR)
- Corrective action plans for issues identified in the PDR have been completed
- CARD is updated and reflects the design in the allocated baseline
- LCSP is updated to reflect development efforts and schedules

4.2.13. Critical Design Review

4.2.13. Critical Design Review

The Critical Design Review (CDR) confirms the system design is stable and is expected to meet system performance requirements, confirms the system is on track to achieve affordability and should cost goals as evidenced by the detailed design documentation, and establishes the system's initial product baseline. The system CDR occurs during the EMD phase and typically marks the end of the integrated system design efforts and readiness to continue with system capability and manufacturing process demonstration activities.

The CDR provides the acquisition community with evidence that the system, down to the lowest system element level, has a reasonable expectation of satisfying the requirements of the system performance specification as derived from the Capability Development Document (CDD) within current cost and schedule constraints.

The CDR establishes the initial product baseline for the system and its constituent system elements. It also establishes requirements and system interfaces for enabling system elements such as support equipment, training system, maintenance, and data systems. At this point the system has reached the necessary level of maturity to start fabricating, integrating, and testing pre-production articles with acceptable risk.

The product baseline describes the detailed design for production, fielding/deployment, and operations and support. The product baseline prescribes all necessary physical (form, fit, and function) characteristics and selected functional characteristics designated for production acceptance testing and production test requirements. It is traceable to the system performance requirements contained in the Capability Development Document (CDD). The initial system element product baseline is established and placed under configuration control at the system element CDR and verified later at the Physical Configuration Audit (PCA). In accordance with DoDI 5000.02, the Program Manager assumes control of the initial product baseline for all Class I configuration changes at the completion of the system level CDR to the extent that the competitive environment permits. This does not necessarily mean that the Program Manager takes delivery and acceptance of the Technical Data Package (TDP) (for more information, see DAG section 4.3.7. Configuration Management Process).

Roles and Responsibilities

The Systems Engineer documents the approach for the CDR in the Systems Engineering Plan (SEP). This includes identification of criteria, and artifacts defining the product baseline.

The Program Manager reviews and approves the approach, ensures the required resources are available, and recommends independent review participants.

The Program Manager and Systems Engineer may hold incremental CDRs for lower-level system elements, culminating with a system-level CDR. The system CDR assesses the final design as captured in system performance specifications for the lower-level system elements; it further ensures that documentation for the detailed design correctly and completely captures each such specification. The Program Manager and Systems Engineer evaluate the detailed designs and associated logistics elements to determine whether they correctly and completely implement all allocated system requirements, and whether they have maintained traceability to the CDD.

The Program Manager's responsibilities include:

- Approve, fund, and staff the system CDR as planned in the SEP developed by the Systems Engineer
- Establish the plan to the System Verification Review (SVR) in applicable contract documents including the SE Management Plan (SEMP), Integrated Master Schedule (IMS), and Integrated Master Plan (IMP)
- Ensure the plan includes independent subject matter experts to participate in each review
- Control the configuration of the Government-controlled subset of the functional, allocated, and product baselines; convene Configuration Steering Boards (CSBs) when changes are warranted

The Systems Engineer's responsibilities include:

- Develop and execute the system CDR plans with established quantifiable review criteria, carefully tailored to satisfy program objectives
- Ensure that the pre-established review criteria have been met to ensure the design has been captured in the allocated baseline and initial product baseline
- Ensure assessments and risks associated with all design constraints and considerations are conducted, documented, and provided (e.g., reliability and maintainability, corrosion, and Environment, Safety, and Occupational Health (ESOH) considerations)
- Determine the root cause of problems, identify corrective actions, and manage to completion
- Monitor and control the execution of the CDR closure plans
- Document the plan to SVR in the SEP and elsewhere as appropriate

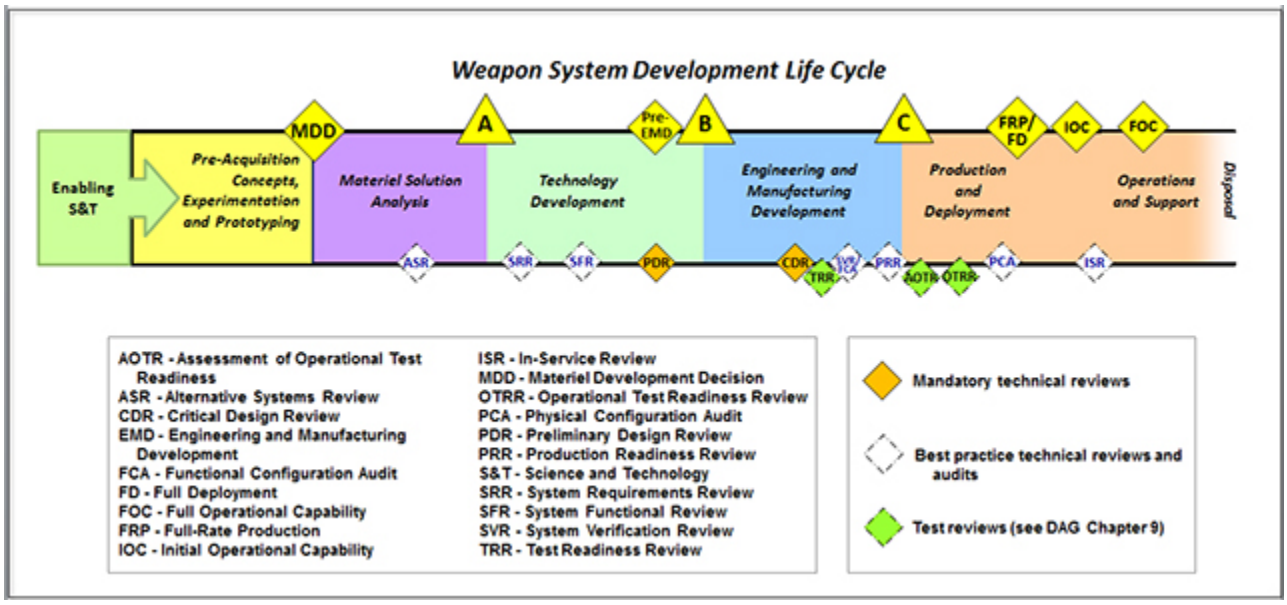
The USD(AT&L) memorandum, "Expected Business Practice: Post-Critical Design Review Reports and Assessments" directs the DASD(SE)) to participate in CDRs for Major Defense Acquisition Programs (MDAPs), and prepare a brief assessment of the program's design

maturity and technical risks that may require Milestone Decision Authority (MDA) attention.

Inputs and Review Criteria

Figure 4.2.13.F1 provides the end-to-end perspective and the integration of SE technical reviews and audits across the acquisition life cycle.

Figure 4.2.13.F1. Weapon System Development Life Cycle



The March 2012 Government Accountability Office (GAO) report, "Assessments of Selected Weapon Programs," suggests a best practice is to achieve design stability at the system-level CDR. A general rule is that 75 to 90 percent of (manufacturing quality) product drawings, software design specification(s), and associated instructions (100 percent for all Critical Safety Items (CSIs) and Critical Application Items (CAIs)) should be complete in order to provide tangible evidence of a stable product design. A prototype demonstration shows that the design is capable of meeting performance requirements.

The CDR review criteria are developed to best support the program's technical scope and risk and are documented in the program's SEP no later than Milestone B. Table 4.2.13.T1 defines the products and associated review criteria. The system-level CDR review should not begin until these criteria are considered met and any prior technical review is complete and its action items closed. A readiness assessment tool for CDR preparation is the DoD CDR Checklist. The CDR is a mandatory technical review.

Table 4.2.13.T1. CDR Products and Criteria

Product	CDR Criteria
Cost Estimate	• Updated Cost Analysis Requirements Description (CARD) is consistent with the approved initial product baseline • System production cost model has been updated, allocated to subsystem level, and tracked against targets
System Baseline Documentation (Functional and/or Allocated and/or Product)	• Detailed design (hardware and software), including interface descriptions are complete and satisfy all requirements in the system functional baseline • Requirements trace among functional, allocated, and initial product baselines are complete and consistent
System Baseline Documentation (Product)	• Key product characteristics having the most impact on system performance, assembly, cost, reliability, and sustainment or ESOH have been identified to support production decisions • Initial product baseline documentation is sufficiently complete and correct to enable hardware fabrication and software coding to proceed with proper configuration management • Assessment of the technical effort and design indicates potential for operational test and evaluation success (operationally effective and suitable) (see DAG Chapter 9 Test and Evaluation) • 100% of Critical Safety Items and Critical Application Items have completed drawings, specifications and instructions • Failure mode, effects, and criticality analysis (FMECA) is complete • Estimate of system reliability and maintainability based on engineering analyses, initial test results or other sources of demonstrated reliability and maintainability • Detailed design satisfies sustainment and Human Systems Integration (HSI) requirements (see DAG Chapter 6 Human Systems Integration) • Software functionality in the approved initial product baseline is consistent with the updated software metrics and resource-loaded schedule • Software and interface documents are sufficiently complete to support the review • Detailed design is producible and assessed to be within the production budget • Process control plans have been developed for critical manufacturing processes • Critical manufacturing processes that affect the key product characteristics have been identified, and the capability to meet design tolerances has been determined • Verification (developmental test and evaluation (DT&E)) assessment to date is consistent with the product baseline and indicates the potential for test and evaluation success (see Test and Evaluation Master Plan (TEMP) and Chief Developmental Tester in DAG Chapter 9 Test and Evaluation)

Product	CDR Criteria
Risk Assessment	• All risk assessments and risk mitigation plans have been updated, documented, formally addressed, and implemented • Test and evaluation strategy defined in the TEMP accounts for risks with a mitigation plan; necessary integration and test resources are documented in the TEMP and current availabilities align with the Program's IMS (Systems Engineer coordinates with Chief Developmental Tester in this area; see DAG Chapter 9 Test and Evaluation) • ESOH risks are known and being mitigated
Technical Plans	• PDR is successfully completed; all PDR actions are closed • Integrating activities of any lower-level CDRs have occurred; identified issues are documented in action plans • All entry criteria stated in the contract (e.g., SOW, SEP, approved SEMP, and system specification) have been satisfied • Adequate processes and metrics are in place for the program to succeed • Program schedule as depicted in the updated IMS (see DAG section 4.3.2.2. Integrated Master Plan/Integrated Master Schedule) is executable (within acceptable technical/cost risks) • Program is properly staffed • Program is executable with the existing budget and the approved initial product baseline • Detailed trade studies and system producibility assessments are under way • Materials and tooling are available to meet the pilot line schedule • Logistics (sustainment) and training systems planning and documentation are sufficiently complete to support the review • Life-Cycle Sustainment Plan (LCSP), including updates on program sustainment development efforts and schedules based on current budgets, test and evaluation results, and firm supportability design features, is approved • Long-lead procurement plans are in place; supply chain assessments are complete

Outputs and Products

The Technical Review Chair determines when the review is complete. Completion of the CDR should provide the following:

- An established system initial product baseline
- Acceptable risks with mitigation plans approved and documented in the IMS
- Updated CARD (or CARD-like document) based on the system Initial product baseline
- Updated program development schedule including fabrication, test and evaluation, software coding, and critical path drivers
- Corrective action plans for issues identified in the PDR
- Updated LCSP, including program sustainment development efforts and schedules based on current budgets, test evaluation results and firm supportability design features

Note that baselines for some supporting items might not be at the detailed level and may lag the system-level CDR. Enabling systems may be on different life-cycle timelines. The CDR agenda

should include a review of all this information, but any statement that all detailed design activity on these systems is complete may lead to misunderstandings. As an example, development of simulators and other training systems tends to lag weapon system development.

4.2.14. System Verification Review/Functional Configuration Audit

4.2.14. System Verification Review/Functional Configuration Audit

The System Verification Review (SVR) is the technical assessment point at which the actual system performance is verified to meet the requirements in the system performance specification and is documented in the system functional baseline. The Functional Configuration Audit (FCA) is the technical audit during which the actual performance of a system element is verified and documented to meet the requirements in the system element performance specification in the allocated baseline. Further information on FCA can be found in MIL-HDBK-61A. SVR and FCA are sometimes used synonymously when the FCA is at the system level. The SVR/FCA typically occurs during the Engineering and Manufacturing Development (EMD) phase.

When a full-up system prototype is not part of the program's acquisition strategy, the FCA is used to validate system element functionality. Other system-level analysis is then used to ascertain whether program risk warrants proceeding to system initial production for Operational Test and Evaluation (OT&E). Verification of system performance is later accomplished on a production system.

A successful SVR/FCA reduces the risk when proceeding into initial production for the system to be used in operational test and evaluation (OT&E). The SVR/FCA is used to:

- Assess whether system development is satisfactorily completed
- Prepare the system for OT&E (see DAG Chapter 9 Test and Evaluation)
- Confirm that the product baseline meets the requirements of the functional baseline and therefore has a high likelihood of meeting the warfighter requirements documented in the Capability Development Document (CDD) and/or Capability Production Document (CPD)

Roles and Responsibilities

The unique Program Manager responsibilities associated with an SVR/FCA include:

- Approve, fund, and staff the SVR/FCA as planned in the Systems Engineering Plan (SEP) developed by the Systems Engineer
- Establish the plan to the Production Readiness Review (PRR) in applicable contract documents including the SE Management Plan (SEMP), Integrated Master Schedule (IMS), and Integrated Master Plan (IMP)
- Ensure the SEP includes independent subject matter experts to participate in each technical review/audit
- Continue to control Class I changes to the system product baseline (see DAG section 4.3.7. Configuration Management Process)

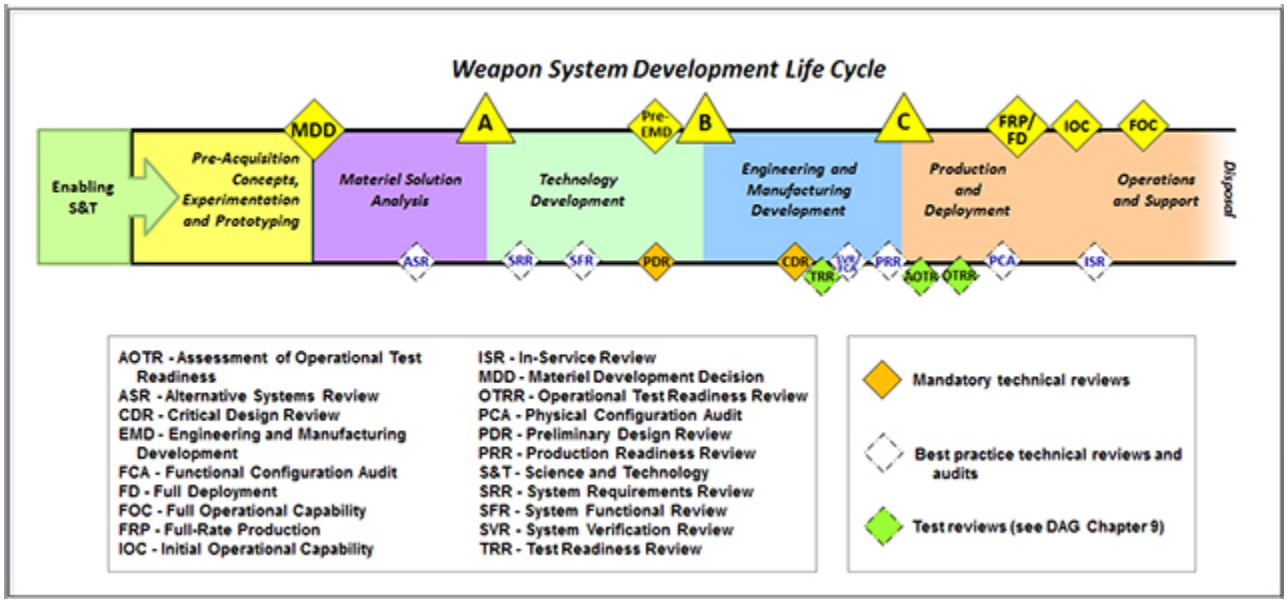
The unique Systems Engineer responsibilities associated with an SVR/FCA include:

- Develop and execute the SVR/FCA plans with established quantifiable review criteria, carefully tailored to satisfy program objectives
- Ensure the pre-established technical review/audit criteria have been met
- Ensure all requirements in the system performance specification have been verified through the appropriate verification method and have been appropriately documented
- Ensure technical risk items associated with the verified system product baseline are identified and analyzed, and mitigation plans are in place
- Monitor and control the execution of the SVR/FCA closure plans
- Ensure adequate plans and resources are in place to accomplish the necessary technical activities between SVR, PRR and Physical Configuration Audit (PCA); these plans should allow for contingencies

Inputs and Review Criteria

Figure 4.2.14.F1 provides the end-to-end perspective and the integration of SE technical reviews and audits across the acquisition life cycle.

Figure 4.2.14.F1. Weapon System Development Life Cycle



The SVR/FCA criteria are developed to best support the program's technical scope and risk and are documented in the program's SEP no later than Milestone B. Table 4.2.14.T1 defines the suggested SVR/FCA products and associated review criteria. The review should not begin until these criteria are considered met and any prior technical review is complete and its action items closed. A readiness assessment tool for SVR preparation is the DoD SVR Checklist. This is a best practice review.

Table 4.2.14.T1. SVR/FCA Products and Criteria

Product	SVR/FCA Criteria
System Baseline Documentation (Functional and/or Allocated) Verification	• Documented achievement of functional and/or allocated baseline requirements through the appropriate documented verification method (analysis, demonstration, examination, testing, or any combination thereof) are reviewed and verified (**Note:** verification testing may include developmental, operational (e.g., Early Operational Assessments (EOAs), Operational Assessments (OAs)) and/or live fire testing) • Assessment that the documented system product baseline for the initial production system has a low risk of operational test failure during OT&E
Risk Assessment	• Identified and documented risks (including ESOH) have been accepted at the appropriate management level prior to initial production for the system to be used in OT&E
Technical Plans	• Detailed plan/schedule has been established and sufficiently resourced to continue development

Outputs and Products

The Technical Review Chair determines when the review is complete. Once the products have been reviewed and approved in SVR/FCA, they provide a sound technical basis for proceeding into initial production for the system to be used in OT&E.

4.2.15. Production Readiness Review

4.2.15. Production Readiness Review

The Production Readiness Review (PRR) for the system determines whether the system design is ready for production, and whether the developer has accomplished adequate production planning for entering Low-Rate Initial Production (LRIP) and Full-Rate Production (FRP). Production readiness increases over time with incremental assessments accomplished at various points in the life cycle of a program.

In the early stages, production readiness assessments should focus on high-level manufacturing concerns such as the need for identifying high-risk and low-yield manufacturing processes or materials, or the requirement for manufacturing development efforts to satisfy design

requirements. As the system design matures, the assessments should focus on adequate production planning, facilities allocation, producibility changes, identification and fabrication of tools and test equipment, and long-lead items. The system PRR, held prior to Milestone C, should provide evidence that the system can be produced with low risk and no breaches in cost, schedule, and performance thresholds. See also the System Capability and Manufacturing Process Demonstration described in DoDI 5000.02 Enclosure 2 paragraph 6.c.(6)(d).

For complex systems, a PRR may be conducted for one or more system elements. In addition, periodic production readiness assessments should be conducted during the Engineering and Manufacturing Development phase to identify and mitigate risks as the design progresses. The incremental reviews lead to an overall system PRR. See DAG section 4.2.8. Technical Reviews and Audits Overview for more on this incremental approach.

Roles and Responsibilities

The unique Program Manager responsibilities associated with a system PRR include:

- Approve, fund, and staff the PRR as planned in the Systems Engineering Plan (SEP) developed by the Systems Engineer
- Establish the plan to Physical Configuration Audit (PCA) in applicable contract documents including the SE Management Plan (SEMP), Integrated Master Schedule (IMS), and Integrated Master Plan (IMP)
- Ensure the plan includes independent subject matter experts to participate in each review
- Determine if the readiness of manufacturing processes, quality management system, and production planning (i.e., facilities, tooling and test equipment capacity, personnel development and certification, process documentation, inventory management, supplier management, etc.) provide low-risk assurances for supporting LRIP and FRP
- Continue to control Class I changes to the system product baseline (see DAG section 4.3.7. Configuration Management Process)

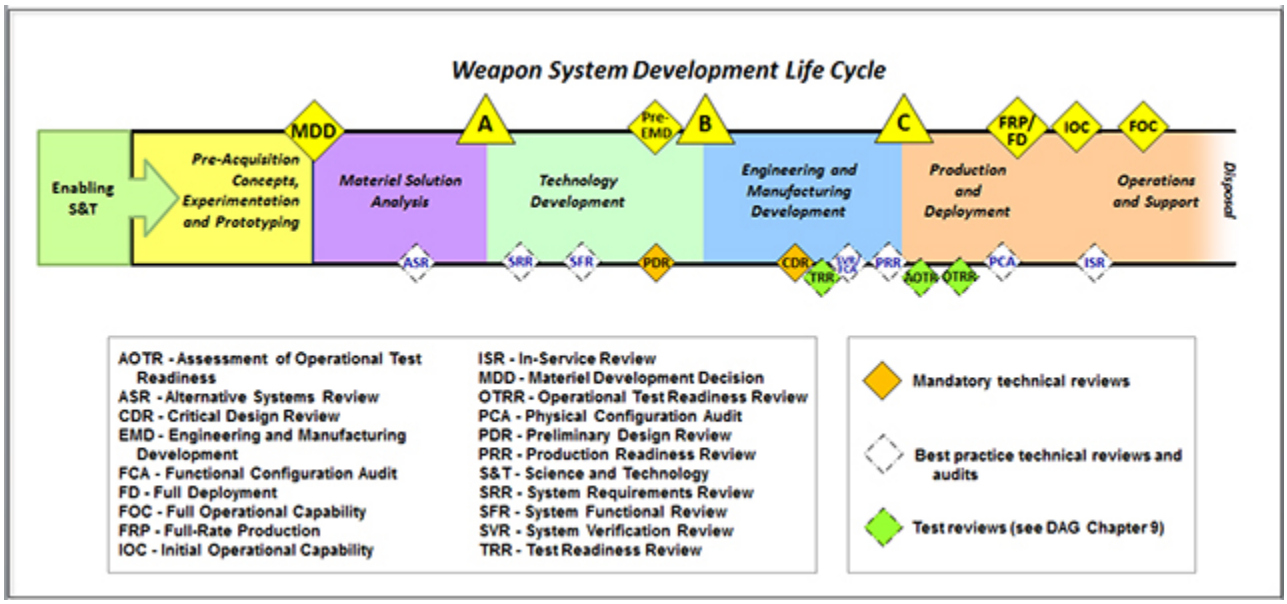
The unique Systems Engineer responsibilities associated with a system PRR include:

- Develop and execute the PRR plans with established quantifiable review criteria, carefully tailored to satisfy program objectives
- Ensure that the pre-established review criteria have been met to ensure the production capability forms a satisfactory, affordable, and sustainable basis for proceeding into LRIP and FRP
- Advise the Program Manager on whether production capability forms a satisfactory, affordable, and sustainable basis for proceeding into LRIP and FRP
- Ensure adequate plans and resources are in place to proceed from PRR to PCA and FRP Decision Review (DR)
- Ensure plans to proceed to PCA and FRP DR allow for contingencies
- Ensure production implementation supports overall performance and maintainability requirements
- Monitor and control the execution of the PRR closure plans

Inputs and Review Criteria

Figure 4.2.15.F1 provides the end-to-end perspective and the integration of SE technical reviews and audits across the acquisition life cycle.

Figure 4.2.15.F1. Weapon System Development Life Cycle



The PRR criteria are developed to best support the program's technical scope and risk and are documented in the program's SEP no later than Milestone B. Table 4.2.15.T1 defines the suggested PRR products and associated review criteria. The review should not begin until these criteria are considered met and any prior technical review is completed and its action items closed. A readiness assessment tool for PRR preparation is the DoD PRR Checklist. This is a best practice review**.**

Table 4.2.15.T1. PRR Products and Criteria

Product	PRR Criteria
Cost Estimate	• System, as designed, is producible within the production budget • Production cost model is based on the stable detailed design and supply chain, and has been validated
Risk Assessment	• Producibility trade studies and risk assessments are completed • Manufacturing, production, and quality risks are identified, and a mitigation plan exists to mitigate those risk(s) • Environment, Safety, and Occupational Health (ESOH) risks are known and mitigated

Product	PRR Criteria
System Baseline Documentation (Product)	• System product baseline is stable and under proper configuration control to enable hardware fabrication in low-rate production • Technologies are mature and proven in the final form, in operational environments • Manufacturing processes are stable and have been demonstrated in a pilot line environment • Adequate production line processes and metrics are in place for the delivery of on-time, quality products
Technical Plans	• Prior readiness reviews are completed and action items closed • Supply chain is stable and adequate to support planned LRIP and FRP • Program is properly staffed with qualified production, quality (engineering and assurance), and manufacturing personnel • Product acceptance system, including acceptance test procedures and associated equipment, has been validated and put under configuration control • Production facilities are ready and required personnel are trained • Delivery schedule is executable (technical/cost risks, long lead items) • Diminishing Manufacturing Sources and Material Shortages (DMSMS) plan is in place and mitigates the risk of obsolescence during LRIP and FRP

A follow-on PRR may be appropriate in the Production and Deployment (PD) phase for the prime contractor and major subcontractors if:

- Changes (from the Engineering and Manufacturing Development (EMD) phase system design) in materials and/or manufacturing processes are required when entering or during the Production and Deployment (P&D) phase
- Production start-up or re-start occurs after a significant shutdown period
- Production start-up is with a new contractor
- The manufacturing site is relocated

The PRR is designed as a system-level preparation tool and should be used for assessing risk as the system transitions from development to FRP. For more information see the approaches described in DAG section 4.3.18.18. Producibility, Quality, and Manufacturing Readiness.

Outputs and Products

The Technical Review Chair determines when the review is complete. Results of the PRR and associated manufacturing readiness assessments are typically documented in a written report or out-brief. The results should be reported based on the criteria documented in the SEP, using the PRR checklist. Another source of information is the Manufacturing Readiness Level Deskbook to be used as appropriate.

4.2.16. Physical Configuration Audit

4.2.16. Physical Configuration Audit

The Physical Configuration Audit (PCA) is a formal examination to verify the "to be fielded" configuration of a validated system against its design and manufacturing documentation. The objective of the PCA is to resolve any discrepancies between the production-representative item that has successfully passed Operational Test and Evaluation (OT&E) and the associated documentation currently under configuration control. A successful PCA provides the Milestone Decision Authority (MDA) with evidence that the product design is stable, the capability meets end-user needs, and production risks are acceptably low. At the conclusion of the PCA, the final product baseline is established and all subsequent changes are processed by formal engineering change action. Further information can be found in MIL-HDBK-61A.

The PCA is an event-driven technical assessment and typically occurs during the Production and Deployment (P&D) phase, after successful system validation but prior to the Full-Rate Production Decision Review (FRP DR). A PCA conducted during FRP may miss the opportunity to avoid costly defects built into production. While the system-level PCA typically occurs before the FRP DR, other system element PCAs may be conducted at various points in advance of the system-level PCA.

A properly conducted and documented PCA provides a major knowledge point in preparation for investment decisions at FRP DR. The PCA confirms:

- Any testing deficiencies have been resolved and appropriate changes implemented; changes to the product baseline have been incorporated into current design documentation
- All production-related activities (tooling, acceptance/inspection equipment, instructions, molds, jigs, and make-buy decisions) are focused on a validated and accurate design
- Any system elements that were affected/redesigned after the completion of the Functional Configuration Audit (FCA) also meet contract requirements
- The manufacturing processes, quality control system, measurement and test equipment, and training are adequately planned, tracked, and controlled

Roles and Responsibilities

The unique Program Manager responsibilities associated with a system PCA include:

- Approve, fund, and staff the PCA as planned in the Systems Engineering Plan (SEP) developed by the Systems Engineer
- Establish the plan to FRP DR in applicable contract documents including the SE Management Plan (SEMP), Integrated Master Schedule (IMS), and Integrated Master Plan (IMP)
- Ensure the plan includes independent subject matter experts to participate in each review
- Determine if the readiness of manufacturing processes, quality management system, and production planning (i.e., facilities, tooling and test equipment capacity, personnel

development and certification, process documentation, inventory management, supplier management, etc.) provide low-risk assurances for supporting FRP
- Continue to control Class I changes to the system product baseline (see DAG section 4.3.7. Configuration Management Process)

The unique Systems Engineer responsibilities associated with a system PCA include:

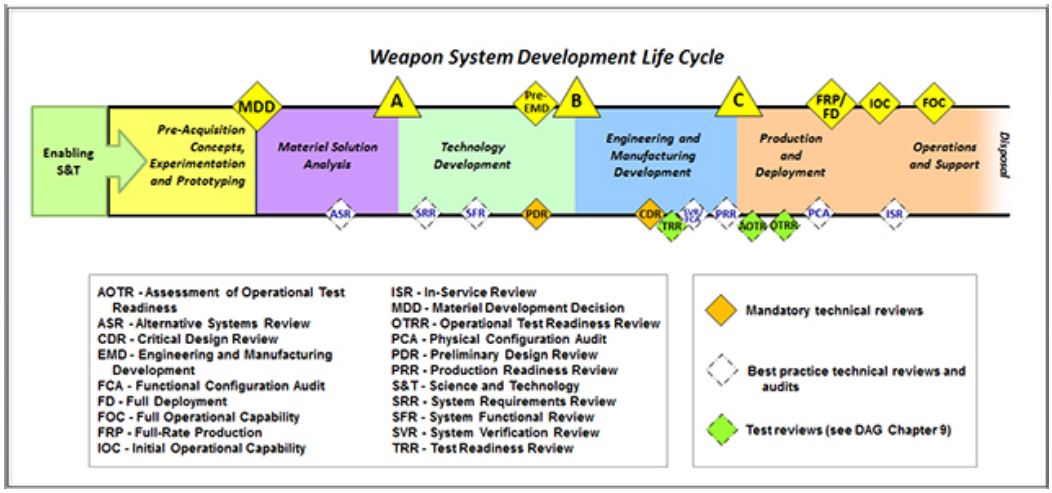
- Develop and execute the PCA plans with established quantifiable review criteria, carefully tailored to satisfy program objectives
- Coordinate with configuration management and manufacturing SMEs and the production contractor/production facility to develop an efficient approach to the PCA
- Identify method(s) of examining the production-representative item (e.g., disassembly, inspection, and reassembly) and verify the item against related design documentation
- Ensure that the pre-established review criteria have been met to ensure the production capability forms a satisfactory, affordable, and sustainable basis for proceeding with FRP
- Advise the Program Manager on whether production capability forms a satisfactory, affordable, and sustainable basis for proceeding into FRP
- Ensure adequate plans and resources are in place to get from PCA to Full Operational Capability (FOC)
- Ensure plans to get to FOC allow for contingencies
- Ensure production implementation supports overall performance and maintainability requirements
- Monitor and control the execution of the PCA closure plans

When the program does not plan to control the detailed design or purchase the item's technical data, the developer should conduct an internal PCA to define the starting point for controlling the detailed design of the item and establishing a product baseline.

Inputs and Audit Criteria

Figure 4.2.16.F1 provides the end-to-end perspective and the integration of SE technical reviews and audits across the acquisition life cycle.

Figure 4.2.16.F1. Weapon System Development Life Cycle



The PCA criteria are developed to best support the program's technical scope and risk and are documented in the program's SEP no later than Milestone C. The PCA is conducted when these criteria are considered to be met.

Table 4.2.16.T1 defines the suggested PCA products and associated review criteria. The review should not begin until the Systems Engineer judges that all criteria have been met. The DoD PCA Checklist and can be used for assessing readiness for the audit. This is a best practice audit.

Table 4.2.16.T1. PCA Products and Criteria

Product	PCA Criteria
Verified Product Baseline Documentation	• Assessment that the system product baseline is complete and accurately reflects the configuration of the representative production item that was inspected and validated through OT&E
Risk Assessment	• Risks are identified and documented at levels low enough to continue with full-rate production and deployment
Technical Plans	• A detailed plan and schedule are established and sufficiently resourced to proceed with full-rate production and deployment

Outputs and Products

The Technical Review Chair determines when the review is complete. The primary output of the PCA is a verified product baseline that accurately reflects the validated system and supports a favorable FRP DR.

4.2.17. In-Service Review

4.2.17. In-Service Review

The In-Service Review (ISR) is a multidisciplined assessment to characterize the in-service health of the deployed system and enabling system elements (training, user manuals, documentation, etc.). The ISR provides feedback to the Program Manager on how well the system is delivering the capability to the warfighter, with acceptable operational performance. In addition, the feedback substantiates in-service support budget priorities.

DoDI 5000.02, Enclosure 2, 8.c.(1)(f) requires DoD Components to conduct continuing reviews to compare expected performance to actual performance. The ISR is typically conducted shortly after Initial Operational Capability (IOC); however, the Program Manager should schedule additional ISRs with the end user until the system is retired. Typical focus areas for additional

ISRs might include: modifications, upgrades, product improvement, technology refresh, and technology insertion (see DAG Chapter 5 Life-Cycle Logistics for additional information). Additional ISRs are typically critical for systems that change more frequently, such as commercial-off-the-shelf and software-intensive systems. The DoD ISR Checklist can be used to plan and implement this review.

Roles and Responsibilities

The Program Manager establishes the relationships between the developer and the end-user to facilitate system feedback and assessment. In addition, the Program Manager determines priorities and approves changes and implementation plans.

The Systems Engineer supports efforts to translate end user feedback into corrective action plans for possible modifications, technology refresh and/or insertion, Diminishing Manufacturing Sources and Material Shortages (DMSMS) issues, and other types of system or system element improvements.

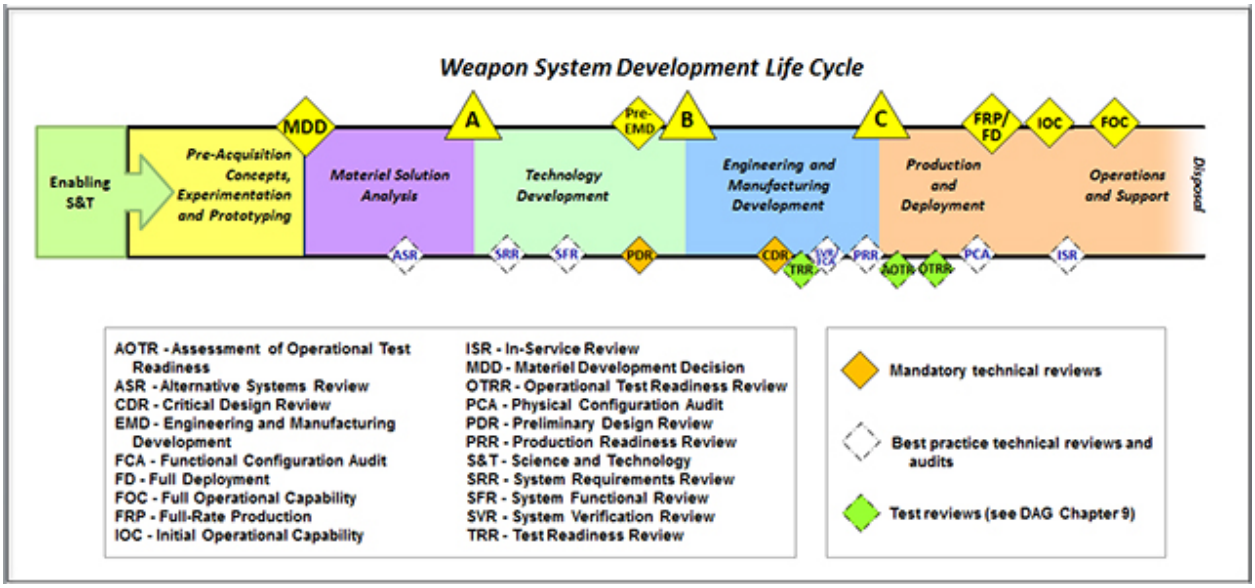
The ISR can be used to:

- Assess risk in the operational environment
- Identify trends in metrics to substantiate in-service budget or corrective actions

Inputs and Review Criteria

Figure 4.2.17.F1 provides the end-to-end perspective and the integration of SE technical reviews and audits across the acquisition life cycle.

Figure 4.2.17.F1. Weapon System Development Life Cycle



To enter an ISR, the review should not begin until these criteria are considered met:

- IOC status has been reached
- System hazard risk assessment has been performed (see DAG section 4.3.18.9. Environment, Safety, and Occupational Health)
- Trend assessment has been performed for preplanned technical metrics

Outputs and Products

The Technical Review Chair determines when the review is complete. The ISR should result in a plan of corrective action for all issues recommended by the Systems Engineer as warranting resolution. Areas of particular interest usually include:

- System problems are categorized and support the operating and support requirements determination process
- Required budgets (in terms of work years) are established to address all system problems in all priority categories
- Current levels of system operational risk and system readiness are quantified and related to current operations and systems and procurement budgets
- Future levels of system operational risk and system readiness are quantified and related to future operations and systems and procurement budgets

4.3. Systems Engineering Processes

4.3.1. Systems Engineering Processes Overview

4.3. Systems Engineering Processes

4.3.1. Systems Engineering Processes Overview

The systems engineering (SE) processes are used by contractor and Government organizations to provide a framework and methodology to plan, manage, and implement technical activities throughout the acquisition life cycle. SE planning and execution should focus on applying the processes and tools in a rigorous, integrated, and disciplined manner to achieve a system solution that balances performance, cost, schedule, and risk. The eight technical management processes provide a consistent framework for managing technical activities and identifying the technical information and events critical to the success of the program. The eight technical processes ensure the system design and the delivered capability reflect the requirements that the stakeholders have expressed. As a whole, the SE processes provide a systematic approach focused on providing needed capability to the operational end user. Successful implementation of the SE processes results in an integrated capability solution that is:

- Responsive to the needs of the user
- Balanced among multiple requirements, design considerations, and program costs and

schedules
- Able to operate in complex system-of-systems (SoS) environments as required

All organizations performing SE should scale their application and use of these processes to the type of product or system being developed. This scaling should reflect the system's maturity and complexity, size and scope, life-cycle phase, and other relevant considerations. Disciplined application of the SE processes provides a technical framework that enables sound decision making, increases product knowledge and system maturity, and helps reduce risk. The following subsections, as indicated in Table 4.3.1.T1, discuss the SE processes in more detail.

Table 4.3.1.T1. Systems Engineering Processes (DAG Chapter 4 subsection)

Technical Management Processes	Technical Processes
Technical Planning (4.3.2)	Stakeholder Requirements Definition (4.3.10)
Decision Analysis (4.3.3)	Requirements Analysis (4.3.11)
Technical Assessment (4.3.4)	Architecture Design (4.3.12)
Requirements Management (4.3.5)	Implementation (4.3.13)
Risk Management (4.3.6)	Integration (4.3.14)
Configuration Management (4.3.7)	Verification (4.3.15)
Technical Data Management (4.3.8)	Validation (4.3.16)
Interface Management (4.3.9)	Transition (4.3.17)

Industry SE process standards that describe best practices in accomplishing SE include, but are not limited to, the following:

- ISO/IEC 15288, Systems and Software Engineering-System Life Cycle Processes
- ISO/IEC 26702, Application and Management of the Systems Engineering Process
- ISO/IEC/IEEE 42010, Architecture Description
- EIA 632, Processes for Engineering a System

Roles, Responsibilities, and Activities

The Program Manager and Systems Engineer use the technical management processes as insight and control functions for the overall technical development of the system throughout the acquisition life cycle. They use the technical processes to design, create, and analyze the system, system elements, and enabling system elements required for production, integration, test, deployment, support, operation, and disposal.

The SE processes, and their constituent activities and tasks, are not meant to be performed in a particular time-dependent or serial sequence. The Program Manager and Systems Engineer apply the processes iteratively, recursively and in parallel (as applicable) throughout the life cycle to translate identified capability needs into balanced and integrated system solutions. The Systems Engineer is responsible for developing the plan and applying the SE processes across the program, monitoring execution throughout the life cycle, and taking necessary steps to improve

process efficiency and effectiveness.

Table 4.3.1.T2 is a representation of how much effort is typically focused on each of the SE processes throughout the acquisition life cycle. The Program Manager and Systems Engineer should apply appropriate resources with requisite skill sets to ensure successful execution of each process.

Table 4.3.1.T2. Notional Emphasis of Systems Engineering Processes Throughout the Defense Weapon System Acquisition Life Cycle

Legend: ● = Major Use; ◉ = Moderate Use; ○ = Minor Use

SE Technical Management and Technical Processes -- Focus Areas in Acquisition Phases

		Pre-MDD	MSA	TD	EMD	P&D	O&S
TECH MGMT PROCESSES	Decision Analysis	●	●	●	●	●	●
	Technical Planning	●	●	●	●	●	●
	Technical Assessment	◉	●	●	●	●	●
	Requirements Management	◉	●	●	●	●	●
	Risk Management	◉	●	●	●	●	●
	Configuration Management	○	◉	●	●	●	●
	Technical Data Management	○	●	●	●	●	●
	Interface Management	◉	●	●	●	●	●
TECHNICAL PROCESSES	Stakeholder Requirements Definition	◉	●	●	◉	○	○
	Requirements Analysis	◉	●	●	●	○	○
	Architecture Design	◉	●	●	●	○	○
	Implementation	○	◉	◉	●	◉	○
	Integration	○	◉	◉	●	●	○
	Verification	○	◉	◉	●	●	◉
	Validation	○	◉	◉	●	●	●
	Transition	○	○	◉	●	●	●

4.3.2. Technical Planning Process

4.3.2. Technical Planning Process

The Technical Planning process includes defining the scope of the technical effort required to develop, field, and sustain the system, as well as providing critical quantitative inputs to program planning and life-cycle cost estimates. Technical planning provides the Program Manager and Systems Engineer with a framework to accomplish the technical activities that collectively

increase product maturity and knowledge and reduce technical risks. Defining the scope of the technical effort provides:

- An accurate basis for program cost and schedule estimates, documented in the Independent Cost Estimate (ICE), Cost Analysis Requirements Description (CARD), and Acquisition Program Baseline (APB);
- A foundation for risk identification and management (see DAG section 4.3.6. Risk Management Process);
- Quantitative measures supporting the Technical Assessment process (see DAG section 4.3.4. Technical Assessment Process) identifying system maturity; and
- An accurately constructed and resourced IMS supporting the assignment of Earned Value.

The resulting program cost estimates and risk assessments are essential to support milestone decisions, establish the plan for accomplishing work against which contract performance is measured, and enable mandatory program certifications (e.g., section 2366a or section 2366b title 10 United States Code).

Technical planning includes the program's plan for technical reviews and audits (see DAG sections 4.2.8. through 4.2.17.). It should also account for resources (skilled workforce, support equipment/tools, facilities, etc.) necessary to develop, test, produce, deploy, and sustain the system.

Technical planning should be performed in conjunction with, and address, key elements and products of all the other SE processes to ensure the program's technical plan is comprehensive and coherent. For example, it should be used with the Technical Assessment process to evaluate the progress and achievements against requirements, plans, and overall program objectives. If significant variances are detected, this process includes re-planning as appropriate.

The Program Manager and Systems Engineer should ensure that technical planning remains current throughout the acquisition life cycle. They should initiate technical planning activities early in the life cycle prior to the Materiel Development Decision (see DAG section 4.2.2. Pre-Materiel Development Decision) and during the Materiel Solution Analysis (MSA) phase (see DAG section 4.2.3. Materiel Solution Analysis Phase). Beginning in MSA, programs begin to capture their technical planning in the Systems Engineering Plan (SEP) (see DAG section 4.1.2. Systems Engineering Plan), which is required at each milestone review from Milestone A to Milestone C. As the system matures and issues arise throughout the life cycle, the Program Manager and Systems Engineer should consistently look for root cause(s) and implement corrective actions in order to enable programmatic and technical success. Modifications to the SE processes and SEP may be required because of root cause and corrective action analysis and implementation.

Activities and Products

The Program Manager is ultimately responsible for all program plans. The Systems Engineer is

responsible for:

- Developing, maintaining and executing the program's SEP
- Tracking alignment of the developer's Systems Engineering Management Plan (SEMP)
- Providing key technical inputs and ensuring SEP alignment to other program plans (Technology Development Strategy/Acquisition Strategy (TDS/AS), Test and Evaluation Strategy/Test and Evaluation Master Plan (TES/TEMP), Life-Cycle Sustainment Plan (LCSP) and Programmatic Environment, Safety, and Occupational Health Evaluation (PESHE)

Technical Planning should reflect the context of the organization and comply with all applicable policies. The Program Manager and Systems Engineer should consider all relevant constraints when identifying technical tasks, sequencing these tasks, and estimating resources and budgets. Inputs to the technical planning process vary over time as the program evolves and the system matures. Technical Planning includes the following activities:

- Defining the scope and objectives of the technical effort
- Identifying constraints and risks
- Establishing roles and responsibilities
- Dividing the program scope and objective into discrete elements
- Identifying technical reviews and audits as well as their timing
- Establishing schedules and costs
- Preparing or updating planning documentation
- Scaling SE processes based on the scope and complexity of the program/system
- Identifying areas for potential tailoring (including rationale) for MDA approval

Key factors that the Systems Engineer should consider when accomplishing technical planning include:

- Capability needs (requirements, gaps, threats, operational context, concept of operations (CONOPS))
- The system concept or materiel solution
- Key interfaces and interdependencies that exist or need to be developed
- The acquisition approach and strategy, from both a business and a contract perspective
- The chosen engineering approach and development strategy
- The test and evaluation approach and strategy, for both developmental and operational testing (See DAG Chapter 9 Test and Evaluation for additional information regarding interactions with the Chief Developmental Tester)
- Program management approach, including organization, processes, and products
- External dependencies and agreements with other systems or organizations that may be in place
- Need date
- Availability of resources, including funds, personnel, facilities, etc.
- Program risks
- Risk mitigation and shrinkage strategies

In addition to the SEP, the technical planning effort supports the development of the following documents:

- Work Breakdown Structure (see DAG section 4.3.2.1. Work Breakdown Structure) - a framework for specifying program objectives
- Integrated Master Plan (see DAG section 4.3.2.2. Integrated Master Plan/Integrated Master Schedule) - an event-based plan consisting of a hierarchy of program events that need to be accomplished
- Integrated Master Schedule (see DAG section 4.3.2.2. Integrated Master Plan/Integrated Master Schedule) - an integrated, networked schedule that contains all lower-level tasks required to support program events

Other useful resources available to assist the Program Manager and Systems Engineer in the Technical Planning process can be found in the "Guidance & Tools" section of the ODASD(SE) Policy and Guidance website.

4.3.2.1. Work Breakdown Structure

4.3.2.1. Work Breakdown Structure

The Work Breakdown Structure (WBS) provides a consistent and visible framework for materiel items and contracts within a program throughout its life cycle. It provides a product-oriented division of tasks by breaking down work scope for authorization, tracking, and reporting purposes. The WBS is defined, developed, and maintained throughout the acquisition life cycle based on a disciplined application of the systems engineering (SE) process. The goal is to develop a WBS that defines the logical relationship among all program elements to a specified level. The WBS integrates technical, cost, and schedule parameters, giving the Program Manager a tool to:

- Ensure traceability of all program activities
- Identify significant risk drivers
- Forecast cost and schedule performance
- Develop corrective action plans as needed

There are two types of WBS: (1) the Program WBS and (2) the Contract WBS (including flow-down reporting requirements). The Program WBS provides a framework for specifying program objectives. Each WBS element provides logical summary levels for assessing technical accomplishments, for supporting the required event-based technical reviews, and for measuring cost and schedule performance. It represents the entire program from the Government Program Manager's responsibility. The contract WBS is the Government - approved WBS for program reporting purposes and includes all program elements (for example, hardware, software, services, data, or facilities), which are the contractor's responsibility. It includes the contractor's discretionary extension to lower levels, in accordance with Government direction and the contract Statement of Work (SOW). The WBS depicts the system as a product-oriented tree, which may be found in a system model. Requirements for developing a WBS are found in MIL-STD-881C. The Program Manager, in conjunction with the Systems Engineer, should develop a

comprehensive WBS early in the program to support planning, cost and schedule estimates, and risk mitigation activities.

The WBS provides a common thread for the Earned Value Management System (EVMS), the Integrated Master Plan (IMP) and the Integrated Master Schedule (IMS), allowing consistency in understanding and communicating program cost and schedule performance. Additional information about EVMS can be found in DAG Chapter 11 Program Management Activities.

Planning tasks by WBS elements serves as the basis for mapping the development of the technical baseline for estimating and scheduling resource requirements (people, facilities, and equipment). By breaking the system into successively smaller pieces, the Program Manager can ensure all system elements and enabling system elements are identified in terms of cost, schedule, and performance goals in order to reduce risk.

4.3.2.2. Integrated Master Plan/Integrated Master Schedule

4.3.2.2. Integrated Master Plan/Integrated Master Schedule

The Integrated Master Plan (IMP) is an event-driven Government document that provides a framework against which all work is accomplished. The IMP aids in defining and documenting tasks required to define, develop, and deliver a system, and to facilitate operation and support of that system throughout its life cycle. The IMP format usually reflects an event - accomplishment - criteria hierarchical structure for program tracking and execution.

The Integrated Master Schedule (IMS) is an event-driven (not time-driven) document primarily focused with product and process development that is resource loaded and includes margin for risk mitigation. The IMS supplements the IMP and is based on the WBS. The IMS describes the work required to complete the effort in sufficient detail to fully demonstrate understanding of the scope and flow of the work, and it enables the Program Manager to better understand the links and relationships among the various activities and the resources supporting them.

DoDI 5000.02 requires use of the IMS, and the Integrated Master Plan and Integrated Master Schedule Preparation and Use Guide provides additional guidance on developing and implementing these technical planning tools.

A program should have an adequate IMP and IMS and should require the same from its contractor(s). The IMP and IMS communicate the expectations of the program team and provide traceability to the management and execution of the program by IPTs. They also provide traceability to the WBS, the contract WBS (CWBS), the Statement of Work (SOW), systems engineering (SE), and risk management, which together define the products and key processes associated with program success.

The IMP and IMS represent the basis for contractor cost reporting and the associated assessments of contract performance, as defined at the Integrated Baseline Review (IBR) (see DAG Chapter 11 Program Management Activities). The IMP and IMS help the Program Manager and Systems Engineer:

- Identify a baseline for program monitoring, reporting, and control
- Plan, execute, and track risk mitigation efforts
- Support resource analysis and leveling, exploration of alternatives, and cost/schedule trade-off studies
- Provide a roadmap for stakeholders
- Enable effective communication within the Government team and with the developer

Activities and Products

The IMP documents the significant criteria necessary to complete the accomplishments, and ties each to a key program event. The IMS expands on the IMP with an integrated network of tasks, subtasks, activities, schedule for deliverables, and milestones with sufficient logic and durations. The IMS also serves as a tool for time-phasing work and assessing technical performance. IMS activities are thus traceable to the IMP and the WBS, and allow integrated assessments of cost, schedule, technical performance, and associated risks. This traceability serves to:

- Identify critical path, milestones, and activities
- Indicate significant constraints and relationships
- Provide current status and forecast completion dates of scheduled work to enable comparison of planned and actual program accomplishments
- Establish a schedule baseline
- Provide horizontal traceability of interrelationships among activities
- Provide interdependent sequencing of all work authorized on the contract in a manner compatible with IMP events and/or key milestones

The IMP and IMS support effective management of program scope, risk, and day-to-day efforts. During the initial stages of a program, the IMP provides an early understanding of the required scope of work, key events, accomplishment criteria, and the likely program structure by depicting the progression of work through the remaining phases. Regular examination of the plan and schedule increases the documented level of detail and provides confidence that these documents have properly identified and captured all essential activities.

Early identification of and adherence to critical path tasks is essential to ensure that the program remains on track toward achieving schedule and cost goals. The IMS provides linkages between tasks to capture the relationship of predecessor and successor tasks required to initiate or complete major tasks. The IMP and IMS collectively assist stakeholder communication by establishing expectations and dependencies, particularly for tasks performed by different organizations.

The Program Manager and Systems Engineer should determine an appropriate level of detail for the IMS. For low-risk programs, developing the IMS at too high a level of detail may fail to show critical path tasks. The IMS for a high-risk program would most likely show lower levels of detail to aid risk management/mitigation efforts but would typically carry a greater maintenance cost (tracking progress and updating status).

The initial IMP and IMS should address significant activities to provide a basis for conducting

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further risk assessments including identification of tasks associated with moderate to high risks that may emerge later in the life cycle. The IMS should be seen as a tool used by stakeholders during each phase of the program. The IMS should identify all risk mitigation activities for easy identification and tracking.

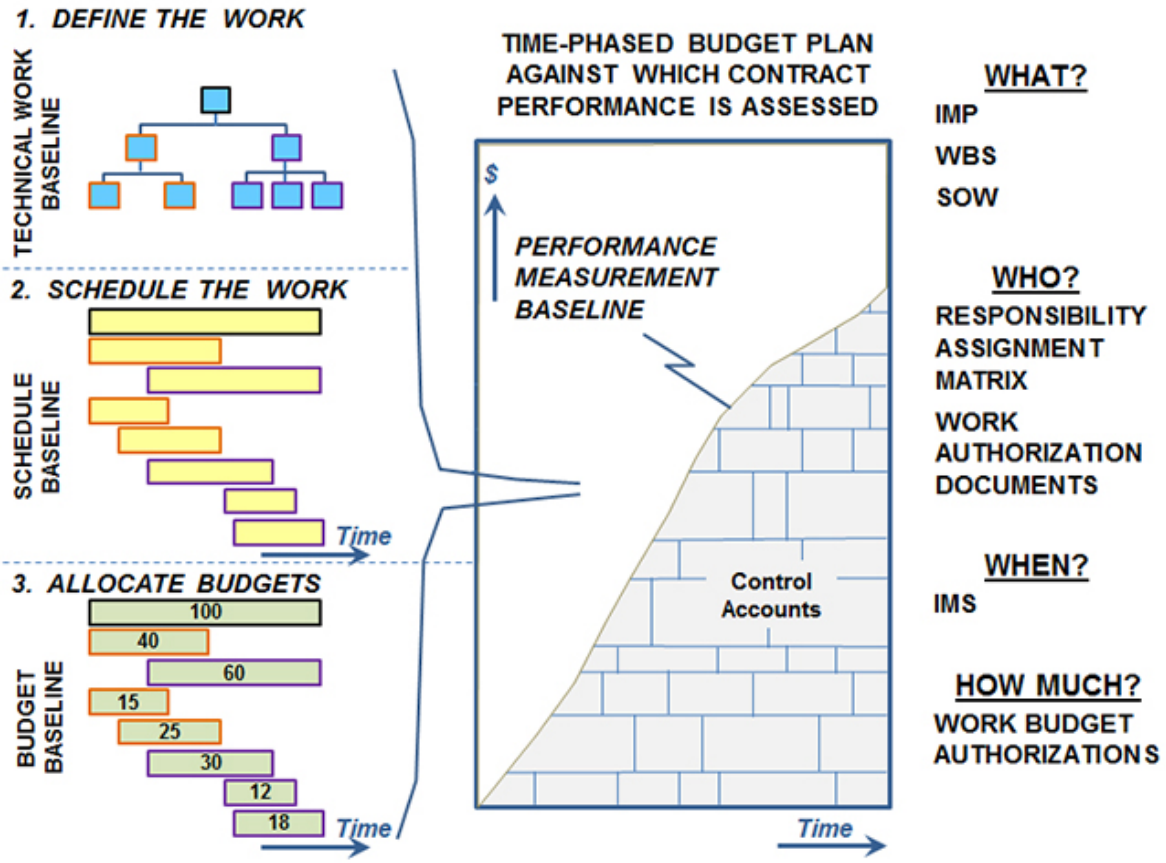
The Program Manager and Systems Engineer should monitor development of the IMS by the developer to ensure that activity durations and resources are reasonable. This oversight aids risk analysis and development of mitigation plans in the event that any of those activities become delayed or over budget. The initial IMP should be part of the preparation for the Milestone A decision.

The Systems Engineer also defines functional and life cycle inputs to integrate SE processes and products and to provide an auditable sequence of tasks and schedules that can be used to measure cost and schedule status. The development and analysis of program IMP/IMS data:

- Permit assessments of the developer's SE processes, activities, efforts, and products
- Contribute to a better understanding of the technical basis of cost and schedule variances
- Provide a framework for developing corrective actions

Figure 4.3.2.2.F1 depicts a hierarchical approach to developing and populating the IMP/IMS.

Figure 4.3.2.2.F1. IMP/IMS Hierarchy and Content



The Program Manager should review the IMP and IMS for completeness, consistency, and compatibility. In this review, the Program Manager should evaluate duration and logic relationships to ensure they accomplish program goals, identify risks, and achieve desired mitigation.

The Systems Engineer should ensure that the SEP and other technical planning documents capture technical review criteria, event-driven outcomes, and mechanisms for assessing technical maturity and risk in a manner consistent with tasks and schedules identified in the IMP/IMS.

4.3.3. Decision Analysis Process

4.3.3. Decision Analysis Process

The Decision Analysis process transforms a broadly stated decision opportunity into a traceable, defendable, and actionable plan. It encompasses one or more discrete analyses at one or more lower (e.g., system element) levels and aggregates them into a higher-level view (e.g., system "scorecard" presentation) relevant to the decision maker and other stakeholders. Decision Analysis can be the central process for formulating, managing, and executing an effective and efficient program at any point in the life cycle.

Decision Analysis and associated trade studies should be integrated with, and mutually supportive of, aspects of several SE processes in the early stages of the program, in particular:

- Technical Planning (see DAG section 4.3.2. Technical Planning Process)
- Technical Assessment (see DAG section 4.3.4. Technical Assessment Process)
- Stakeholder Requirements Definition (see DAG section 4.3.10. Stakeholder Requirements Definition Process)
- Requirements Analysis (see DAG section 4.3.11. Requirements Analysis Process)
- Architecture Design (see DAG section 4.3.12. Architecture Design Process)

A well-executed decision analysis or trade study helps the Program Manager and the Systems Engineer understand the impact of various uncertainties, identify one or more course(s) of action that balance competing objectives, and objectively communicate the results to decision makers. As such, it provides the basis for selecting a viable and effective alternative from among many under consideration.

Decision Analysis applies to technical decisions at all levels, from evaluating top-level architectural concepts to sizing major system elements to selecting small design details. The breadth and depth of the analysis should be scaled to both the scope of the decision and the needs and expectations of the decision maker(s).

Activities and Products

Decision Analysis teams generally include a lead analyst with a suite of reasoning tools; subject matter experts with access to appropriate models and analytical tools; and a representative set of end users and other stakeholders. A robust Decision Analysis process acknowledges that the

decision maker has full responsibility, authority, and accountability for the decision at hand.

Decision Analysis typically includes the following steps:

- Review requirements and assumptions to establish the overall decision context
- Frame/structure the decision in terms of supporting program/project objectives
- Identify methods and tools to be used in the analyses (see DAG section 4.3.19. Tools and Techniques)
- Develop decision criteria (objectives and measures), criteria weight, and associated rationale
- Convey and track assumptions
- Identify and define alternatives to be evaluated (for high-level analyses these are generally directed, although additional ones may arise during the course of the analysis)
- Analyze and assess alternatives against criteria
- Synthesize results
- Analyze sensitivities
- Develop decision briefing with action/implementation plan(s)
- Make appropriate recommendation(s) to decision maker as expected/requested

Sound recommendations and action plans are the principal output of a well-framed and well-executed Decision Analysis process. The ability to drill down quickly from overall trade space visualizations to detailed analyses that support the synthesized views is particularly useful to decision makers in understanding the basis of observations and conclusions.

4.3.4. Technical Assessment Process

4.3.4. Technical Assessment Process

The Technical Assessment process allows the Systems Engineer to compare achieved results against defined criteria to provide a fact-based understanding of the current level of product knowledge, technical maturity, program status, and technical risk. This assessment results in a better understanding of the health and maturity of the program, giving the Program Manager a sound technical basis upon which to make program decisions.

Disciplined technical assessment activities should begin early in the life cycle. They should initially examine the status of development planning activities and efforts in the Materiel Solution Analysis (MSA) phase. During the Technology Development (TD) and Engineering and Manufacturing Development (EMD) phases, technical assessment can provide a basis for tracking development of the system and lower-level system element designs. Disciplined technical assessment supports the establishment of the various baselines and the achievement of system verification. Technical assessment activities are also used in manufacturing and production activities during the Production and Deployment (P&D) phase, and these activities continue through the Operations and Support (O&S) phase in support of reliability growth and sustainment engineering efforts.

The Program Manager and Systems Engineer evaluate technical maturity in support of program

decisions at the key event driven technical reviews and audits (see DAG sections 4.2.8. through 4.2.17.) that occur throughout the acquisition life cycle. The Program Manager and Systems Engineer use various measures and metrics, including Technical Performance Measures (TPM) and leading indicators, to gauge technical progress against planned goals, objectives, and requirements. See DAG sections 4.3.4.1. Technical Measurement and Metrics and 4.3.4.2. Technical Performance Measures for more information on measures/metrics and TPMs, respectively. The Program Support Review (PSR) (see DAG section 4.3.4.3. Program Support Review) is an assessment to identify and resolve planning and execution issues well before an upcoming acquisition milestone review.

Technical assessments against agreed-upon measures enable data-driven decisions. Evidence-based evaluations that communicate progress and technical risk are essential for the Program Manager to determine the need for revised program plans or technical risk mitigation actions throughout the acquisition life cycle.

Technical Assessment provides:

- A determination of the program's progress against plans (resource, schedule, and performance)
- A basis to identify and quantify technical risks
- A rigorous method to define corrective actions that may be needed to address and resolve identified technical risks

Activities and Products

The Program Manager should ensure that technical assessments occur throughout the life cycle, and that appropriate resources are available to allow for program office personnel and independent subject matter experts to participate. The Program Manager and Systems Engineer should jointly plan for event-driven technical reviews and audits. Review criteria (e.g., completion of baseline documents and artifacts appropriate for the review) should support objective assessments of technical progress, maturity, and risk.

When required, the Program Manager should approve the performance measurement baseline (PMB) (see DAG Chapter 11 Program Management Activities) to capture time-phased measures against the Work Breakdown Structure (WBS) (see DAG section 4.3.2.1. Technical Measurement and Metrics) and a resource-allocated Integrated Master Schedule (IMS) (see DAG section 4.3.2.2. Integrated Master Plan/Integrated Master Schedule).

The Systems Engineer assists the Program Manager in planning and conducting the Technical Assessment process. This includes advising on technical reviews and audits, defining the technical documentation and artifacts that serve as review criteria for each review/audit, and identifying TPMs. Specific activities include:

- Establishing event-driven technical planning
- Identifying appropriate measures and metrics
- Identifying performance measures to assess program health and technical progress

- Conducting analyses to determine risk and to develop risk mitigation strategies
- Conducting assessments of technical maturity, process health and stability, and risk to communicate progress to stakeholders and authorities at key decision points
- Proposing changes in the technical approach to address risk mitigation activities
- Advising the Program Manager regarding the technical readiness of the program to proceed to the next phase of effort
- Obtaining independent subject matter experts as appropriate for reviews and audits

Technical assessments have close linkages to the Technical Planning and Decision Analysis processes (see DAG section 4.3.2. Technical Planning Process and 4.3.3. Decision Analysis Process, respectively); however, all SE processes (see DAG sections 4.3.2. through 4.3.17.) support activities that contribute to the assessment of program status, technical maturity, and risk in various areas (e.g., schedule, technology, manufacturing, threat).

Inputs to the Technical Assessment process should include approved program plans "(e.g., Acquisition Program Baseline, Systems Engineering Plan, TPMs, etc.), engineering products (i.e., drawings, specifications and reports, prototypes, system elements, and engineering development modules), and current performance metrics. Outputs may include various reports and findings (e.g., technical review reports, corrective actions, Program Support Review findings, or test reports).

4.3.4.1. Technical Measurement and Metrics

4.3.4.1. Technical Measurement and Metrics

Technical Measurement is the method of collecting and providing information to Program Managers and Systems Engineers at predefined intervals for decision making. Metrics constitute the data that identify the need for improvement (i.e., the facts and trends of process performance) and provide a basis for assessing the improvements.

Measures and metrics assist the Program Manager and the Systems Engineer in efforts to obtain insight into issues that have real or projected impacts on cost, schedule, performance, and risk. These issues can be at any level: the entire system, any of the various system elements or enabling system elements, and any or all of the SE processes in use across the program. This insight enables the Program Manager and others in leadership positions to make informed decisions.

Analysis of technical measures and metrics, in terms of progress against established plans, can reveal trends and provide indicators of future results. The Program Manager and Systems Engineer can use these trends and indicators to assess risk and make appropriate changes to program planning to mitigate potentially unfavorable outcomes.

Activities and Products

Programs document their strategy for identifying, prioritizing, and selecting the set of metrics for monitoring and tracking SE activities and performance in the Systems Engineering Plan (SEP).

The measures/metrics strategy should include:

- An overview of the measurement planning and metrics selection process appropriate for the life-cycle phase
- The approach to monitor execution to the established plan
- Identification of roles, responsibilities, and authorities

The SEP requires two types of defined metrics:

- Technical Performance Measures (TPM) derived from Key Performance Parameters (KPPs) and Key System Attributes (KSAs) aid in assessing product maturity (see DAG section 4.3.4.2. Technical Performance Measures)
- Technical progress (at both the system and system element levels) should address product knowledge and therefore vary by phase throughout the life cycle

In addition to TPMs and product measures, the Program Manager and the Systems Engineer should ensure that technical planning identifies measures, metrics, and leading indicators to assess the effectiveness of SE process execution within both the Government program office and the developer's SE organization. TPMs should be managed by the cognizant Integrated Product Team (IPT).

Areas in which measures and metrics should be monitored include but are not limited to:

- Software metrics (e.g., size, complexity, reuse, defects, productivity)
- Hardware metrics (space, weight and power (SWaP), processing margin, axle loading, available RAM, etc.)
- Technical staffing
- Technology maturity
- Affordability
- Risk Mitigation
- Schedule
- Quality / manufacturing / production measures (e.g., defects, first pass yields, process escapes)
- Infrastructure measures (e.g., capacity, availability, utilization of facilities and equipment)
- Design/development process measures (e.g., drawing releases, software modules, subsystem integration tasks, defined/documented interfaces, deviations, waivers, etc.)

4.3.4.2. Technical Performance Measures

4.3.4.2. Technical Performance Measures

Technical Performance Measures (TPMs) are a subset of metrics and measures that evaluate technical progress (i.e., product maturity). TPM data support evidence-based decisions at key knowledge points such as technical reviews and audits or milestone decisions. TPMs compare the actual versus planned technical development and design. They report progress in the degree

to which system performance requirements are met. Systems engineering (SE) uses TPMs to balance cost, schedule, and performance throughout the life cycle when integrated with other management methods such as the Work Breakdown Structure (WBS) and Earned Value Management System (EVMS).

Effective TPMs support assessment of design and integration progress toward achieving Key Performance Parameters (KPPs) and Key System Attributes (KSAs). Subjective items such as improved quality, management responsiveness, or timeliness are difficult to measure and are not suitable as TPMs. Regular progress assessments toward meeting TPMs should occur in management reviews with formal documentation in technical reports and test data.

The program's Systems Engineering Plan (SEP) includes a minimum set of TPMs and the plan to achieve them. The planning should show TPM values as a function of time, aligned with key points in the program schedule (e.g., technical reviews). Decision makers can see progress toward achieving the KPPs and KSAs by reviewing actual values (achieved through analysis, test, demonstration, or other measurement) against planned values.

Each parameter selected as a TPM should:

- Have a time-phased profile with tolerance bands that can be predicted and substantiated during design, development, and test
- Be directly measurable during testing or readily derivable from analysis
- Be derived from the functional baseline and/or allocated baseline
- Provide an indication of risk associated with the system's ability to meet specified performance requirements
- Be written using statistical criteria whenever possible

Activities and Products

Systems Engineers from both the Government and the developer, in consultation with the end user, identify a limited number of parameters for consideration as TPMs. This generally occurs as part of the Architecture Design process (see DAG section 4.3.12. Architecture Design Process), in conjunction with development of the physical architecture and allocation of requirements to system elements. As the program matures, the Technical Assessment and Risk Management processes (see DAG sections 4.3.4. Technical Assessment Process and 4.3.6. Risk Management Process, respectively) should inform the Program Manager and the Systems Engineer of progress on risk mitigation actions, as well as emerging risks that could warrant adding attributes that map to a medium or high risk on the list of TPMs.

The Program Manager, in coordination with the Systems Engineer and developer, approves selected TPMs. The Program Manager should appropriately delegate responsibility for management and reporting TPMs. The Systems Engineer defines, collects, and analyzes performance measurement data for all TPMs to assess performance over time against threshold and objective values. The Systems Engineer should assess all TPMs at each technical review and audit.

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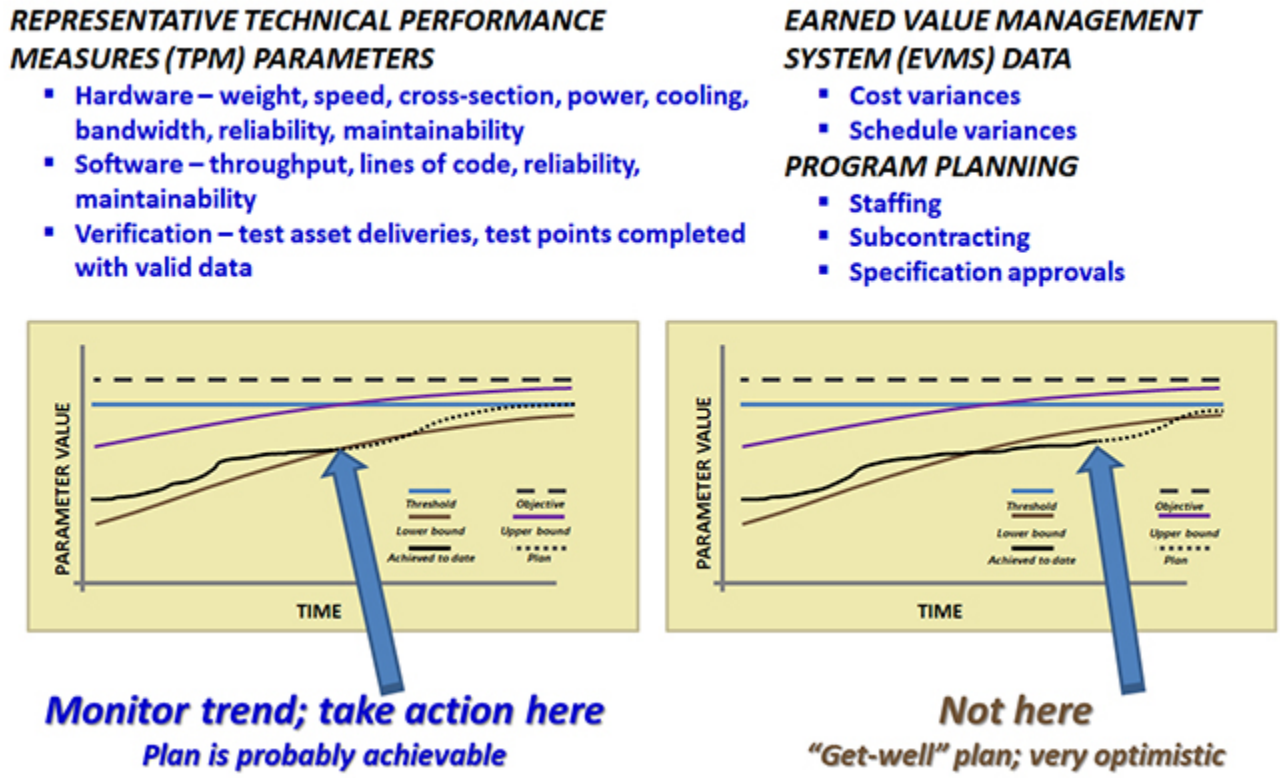
The technical effort documented in the SEP should reflect the events and measurement activities needed for TPM reporting. TPM tracking should be an integral part of the developer's technical planning, and contractors should capture TPM tracking in their Systems Engineering Management Plan (SEMP).

TPM reporting should be in terms of actual versus planned progress, plotted as a function of time and aligned with key points in the program schedule (e.g., technical reviews). A continuous (historical) plot of planned and actual values for each TPM, Earned Value Management System (EVMS) data, and program planning information enables assessment of performance trends (i.e., progress-to-plan relationships with respect to both objective and threshold values).

Figure 4.3.4.2.F1 depicts how leading indicators can influence risk mitigation activities.

Figure 4.3.4.2.F1. Leading Indicators Influence Risk Mitigation Planning



4.3.4.3. Program Support Review

4.3.4.3. Program Support Review

The Office of the Deputy Assistant Secretary of Defense for Systems Engineering (ODASD(SE)) conducts PSRs on ACAT ID and IAM programs to help shape the program's technical planning and management approaches. Like any independent review, the PSR is a technical assessment tool intended to prevent problems by early recognition of risks and identification of proposed

mitigation activities. PSR requirements appear in DoDI 5000.02.

Early conduct of PSRs should help the Program Manager identify and resolve any program planning or execution issues well before major program decisions. Table 4.3.4.3.T1 lists important PSR attributes.

Table 4.3.4.3.T1 PSR Attributes

Cross-functional	• No "stovepipes" • All reviewers look at multiple areas • All observations and comments are adjudicated with the entire team and program office
Multidisciplinary	• Wide range of functional representation (internal ODASD(SE), AT&L, consultants) • Wide range of reviewer expertise • Multiple reviews look at each area
Independent	• Minimize "program experts" • No Government or contractor competitors • No program advocates or antagonists
Consistent	• Essential to identify and understand common issues • Ensure all potential risks are considered • Treat all programs equally and fairly
Tailorable	• Adapt to type of review • Adapt focus on identified issues

Activities and Products

When practical, the initial PSR occurs nine to twelve months before a milestone decision review; a follow-up review (two to three months prior to the milestone) assesses the implementation of key recommendations and mitigation of risks in order to improve program planning and execution. The PSR typically consists of two- to three-day visits to the program office (and developer(s) as applicable).

PSRs focus on all SE processes appropriate to the life-cycle phase but are broader in scope to consider all aspects of acquisition management, including resource planning, management methods and tools, earned value management, logistics, and other areas. The Defense Acquisition Program Support (DAPS) Methodology is a source for tailorable criteria and review questions and helps ensure consistency in reviews. The DAPS Methodology includes:

- Mission capabilities / requirements generation
- Resources
- Management

- Technical planning and process
- Program performance

Insights from PSRs aid the development of the Systems Engineering Plan (SEP) (see DAG section 4.1.2. Systems Engineering Plan) and the Request for Proposals (RFPs), and ensure that the program has adequately addressed SE equities in these documents. After its engagement with the program in preparation for the pre-Milestone A PSR, the ODASD(SE) staff maintains continuous engagement with the program to monitor its execution of the planning reflected in the SEP. PSRs prior to Milestones B, C, and the Full-Rate Production decision can make use of information already vetted during SE WIPT meetings, various technical reviews (see DAG sections 4.2.8. through 4.2.14.), and program management reviews in order to help reduce the PSR burden on the program office and developer staff. PSR action items are documented in the milestone review's Acquisition Decision Memorandum.

4.3.5. Requirements Management Process

4.3.5. Requirements Management Process

Programs should maintain a current and approved set of requirements over the entire acquisition life cycle. The Requirements Management process helps ensure delivery of capability that meets intended mission performance to the operational end user.

The end-user needs are usually identified in operational terms at the system level during implementation of the Stakeholder Requirements Definition and Requirements Analysis processes; see DAG section 4.3.10. Stakeholder Requirements Definition Process and 4.3.11. Requirements Analysis, respectively. Through the Requirements Management process, the Systems Engineer tracks requirements changes and maintains traceability of end-user needs to the system performance specification and ultimately the delivered capability. As the system design evolves to lower levels of detail, the Systems Engineer traces the high-level requirements down to the system elements through the lowest level of the design. Requirements Management provides bottom-up traceability from any derived lower-level requirement up to the applicable source (system-level requirement) from which it originates. This bidirectional traceability is the key to effective management of system requirements. It enables the development of an analytical understanding of any system-wide effects of changes to requirements for a given system element, updating requirements documentation with rationale and impacts for approved changes. At the same time, bi-directional traceability ensures that approved changes do not create any "orphaned" lower-level requirements (i.e., that all bottom-up relationships to applicable system-level requirements remain valid after the change). Bidirectional traceability also ensures that higher-level requirements are properly flowed to lower-level requirements and system element designs so that there are no "childless parent" higher-level requirements (i.e., each high-level requirement is ultimately being addressed by lower-level requirements and system element designs).

Robust Requirements Management, implemented in synchronization with the program’s Configuration Management process (see DAG section 4.3.7. Configuration Management Process), can help the program to avoid or mitigate unintended or unanticipated consequences of

changes through rigorous documentation of the system performance specification. Thoughtful analysis and management of requirements can help the lay foundation for system affordability.

Activities and Products

The Program Manager should keep leadership and all stakeholders informed of cost, schedule, and performance impacts associated with requirement changes and requirements growth.

The Systems Engineer establishes and maintains a Requirements Traceability Matrix (RTM) that captures all requirements in the system performance specification, their decomposition/derivation and allocation history, and rationale for all entries and changes. The requirements should be:

- Traceable to and from the stated user needs
- Correctly allocated, with potential effects of proposed changes fully investigated, understood, and communicated to the Program Manager
- Feasibly allocated, i.e., lower-level system elements cannot have the same or wider tolerance bands as those of the higher-level system elements into which they are incorporated

All affected stakeholders and decision makers should fully understand the effects of proposed changes to requirements at the system or system element level before they accept any changes for incorporation into the design. The RTM provides significant benefits during trade-off analysis activities since it captures the system-wide effects of proposed changes to established requirements.

DAG section 4.3.19. Tools and Techniques contains information about SE tools generally employed in the Requirements Management process. There are many commercial software packages specifically designed for the traceability aspect of Requirements Management, from top-level operational requirements down to the lowest-level system elements in the Work Breakdown Structure.

4.3.6. Risk Management Process

4.3.6. Risk Management Process

The Risk Management process is the overarching process that encompasses identification, analysis, mitigation planning, mitigation plan implementation, and tracking of program risks. Risk management is the primary method of mitigating program uncertainties and is therefore critical to achieving cost, schedule, and performance goals at every stage of the life cycle. Effectively managing risks helps the Program Manager and Systems Engineer develop and maintain a system's technical performance, and ensure realistic life-cycle cost and schedule estimates.

DoDI 5000.02 requires that technical and programmatic risks be managed in all life cycle phases. A program's Technology Development Strategy (TDS) or Acquisition Strategy (AS), and

Systems Engineering Plan (SEP) should address risks and should describe the program's risk management process. DAG section 4.3.18.9. Environment, Safety, and Occupational Health contains information regarding ESOH related risk management.

Risk Management is most effective when fully integrated with the program's SE and management processes. Identification of risk drivers, dependencies, root causes, and corrective action, as well as consequence management are key elements of this integration.

By definition, a risk is an unwanted event that may or may not occur in the future. A risk has three components:

- A future (yet-to-happen) root cause that, if corrected or eliminated, would be prevented along with its potential consequences
- A probability (or likelihood), assessed at the present time, of that future root cause occurring
- The consequence (or impact) of that future occurrence

A "Condition-If-Then" construct expresses risk as a function of its root cause, probability, and consequence. This construct generally reveals opportunities to not only mitigate the potential consequences of the risk occurring but also eliminate its root cause(s). As a best practice, risk mitigation plans should focus more on the causal factors that enable the risk's existence rather than on consequence management. Eliminating the root cause of a risk avoids its consequences.

A risk is an unwanted future event that may or may not occur, meaning it has a probability of occurrence of less than one. An issue is an unwanted event that has occurred or is certain to occur in the future (in other words, a probability equal to one). Thus, an issue differs from a risk only in that it is not a probabilistic event. While Program Managers and Systems Engineers can use Risk Management approaches to deal with issues, they should remember that issue management applies resources to current issues or problems. In contrast, risk management proactively applies resources to identify and mitigate future potential root causes and their consequences. Risk management includes the condition when mitigation attempts fail and the risk is realized. The challenge for the Program Manager and Systems Engineer is to balance how they choose to deal with issues and risks, since they encounter both over the life of the program. The Program Manager and Systems Engineer should clearly define, assess, and consider technical and programmatic off ramps if the program cannot be adequately advanced given schedule and budget.

Activities and Products

Because risks can occur in any aspect of a program, it is important to recognize that all program team members and stakeholders have a responsibility to identify risks and report them to the Program Manager and Systems Engineer. Stakeholders also should be invited to participate in risk analysis and mitigation activities as requested or directed.

The Systems Engineer is responsible for prioritizing identified technical risks and developing mitigation actions. The Program Manager reviews and approves the risk priorities and mitigation

plans and ensures required resources are available to implement the mitigation plans.

Risk Management encompasses several significant activities as outlined in Table 4.3.6.T1.

Table 4.3.6.T1. Risk Management Process Activities

Activity	Intent is to answer the question
Risk Identification	What can go wrong? What is the root cause?
Risk Analysis	How big is the risk? What is the probability of occurrence? What is the consequence of occurrence?
Risk Mitigation Planning	What is the program approach (cost, schedule, and technical) for addressing this potential root cause or unfavorable consequence?
Mitigation Plan Implementation	How can the planned risk mitigation be implemented? How do we ensure successful risk mitigation occurs?
Risk Tracking	How are risk mitigation plans going?

Early identification of affordability risk drivers is critical to program success. The investigation of both budgetary (long-term) and cost (near-term) aspects of affordability should continue throughout the acquisition life cycle. The Program Manager and Systems Engineer should carefully examine the technical trade space around budget and cost drivers for opportunities to eliminate or manage affordability concerns before they materialize. See DAG section 4.3.18.2. Affordability - Systems Engineering Trade-Off Analyses for more information on SE trades related to affordability.

Additional information on Risk Management is available in:

- Risk Management Guide for DoD Acquisition (Also see DAG Chapter 11 Program Management Activities for more information on the Program Manager's role in Risk Management)
- MIL-STD-882E, "DoD Standard Practice for System Safety", May 11, 2012
- Joint Capabilities Integration and Development System (JCIDS) Manual (requires Common Access Card (CAC) to access website), January 19, 2012

Table 4.3.6.T2 provides insights into the emphasis of Risk Management throughout the acquisition life cycle. Regardless of phase, several best practices may apply to a program's Risk Management process:

- As designs mature, understanding of schedule alignment, integration challenges, and programmatic functions increase, allowing the decision makers to better assess the risks associated with a given approach.
- Trade studies at various levels (e.g., technology maturation approaches, contracting strategy, material selections, etc.) provide decision support information in the context of risk and affordability throughout the life cycle. See DAG sections 4.3.3. Decision

Analysis Process and 4.3.18.2. Affordability - Systems Engineering Trade-Off Analyses for additional information.

- Supply chain risk management (SCRM) should occur throughout the acquisition life cycle. SCRM includes working with appropriate DoD and Office of the Director of National Intelligence (ODNI) organizations on program threats (foreign and counterintelligence), technology vulnerabilities, contractor threat assessments, counterintelligence vulnerabilities, and global distribution risks.
- Quality risks throughout the supply chain can have a drastic impact on performance, cost, and schedule, as well as overall customer satisfaction. Robust quality management systems and processes focused on continuous improvement are essential to the delivery of safe, reliable, and affordable products.

Table 4.3.6.T2. Focus of Risk Management Process by Phase

Phase	Focus	Products / Outputs (Risk Considerations)	Measures / Metrics
Pre-MDD	Risk assessment of the effort/approach, early assessments of complexity, technical maturity, ability to close or reduce gaps Mitigation measures include resourcing teams for further detailed evaluation		Identify operational risks associated with capability gaps, measured in terms of probability and consequence Estimate resources to implement recommendations to close or mitigate capability gaps and reduce operational risk Identify dependencies and constraints (e.g., capability integration and interoperability with other systems or materiel solutions) associated with closing or mitigating capability gaps

Phase	Focus	Products / Outputs (Risk Considerations)	Measures / Metrics
MSA	Risk identification as an element of the Analysis of Alternatives (AoA), other technical analysis, and Milestone A entrance criteria Risk assessments to support selection of the preferred materiel solution and appropriate acquisition strategy Vendor viability, contract strategy, acquisition strategy, technology maturity, resource availability, user expectations Acquisition strategy evaluations include risk considerations of contractor availability, technical maturity, environmental, and operational dimensions Mitigation approaches include contract approach, prototype, and parallel development	SE contributions to AoA Report SEP and SE contributions to TDS that highlight how risk areas identified in the AoA are managed or mitigated in the TD phase Selection of alternative solutions to include overall risk of achieving desired capabilities within cost and schedule estimates Risk input to AoA; overall risk assessment and its integration into cost and schedule estimates	A quantitative analytical comparison of the operational effectiveness, suitability, and life-cycle cost of candidate materiel solutions A list of critical technologies (CT) associated with each candidate materiel solution, including measures of technology maturity, integration risk, manufacturing feasibility, CT supply chain risk Quantification of performance, cost, and schedule risks associated with each alternative
TD	Risk Management as a driver for technology readiness, preliminary design, and Milestone B entrance criteria	Technology maturity and risk reduction Validation of CT maturity for a materiel solution from prototypes, experimentation, or other form of demonstration Validation of CT supplier/vendor trustworthiness from a supply chain integrity risk perspective Risk reduction through competitive prototyping: • Broadens the opportunity for technology maturation by engaging multiple parties to compete for technology prototypes • Can help the program identify the nature of risk at the subsystem/ system level (functionality, performance, or affordability) Risks associated with preliminary design	Measures that demonstrate reduced technology maturity risks with respect to CT developers and producers • Vendor viability in terms of business health, market position, industry outlook stability • Assessments of the CT competitive environment to assess reliance risk on a single vendor/supplier Technology Readiness Levels (TRL) as the metric to assess CT maturity Affordability monitoring Continuous should cost estimation Assessment that preliminary design has high likelihood of satisfying the need within cost and schedule constraints

Phase	Focus	Products / Outputs (Risk Considerations)	Measures / Metrics
EMD	Risk Management as an element of development, full system integration, and Milestone C entrance criteria	EMD Risk Management processes, procedures, and plan Risk mitigation for establishment of qualification requirements throughout the supply chain Special emphasis: • Requirements • Risk management • Affordability risk management • Supply chain risk management Should cost assessments EMD risk management plan that includes addressing the above focus areas; include a sustainment risk management plan as part of the program's overall EMD risk management plan (Life-Cycle Sustainment Plan (LCSP)) At the Critical Design Review (CDR), identify risks and mitigation plans for achieving a fully verified functional baseline in a timely fashion	PM's Risk Management Dashboard focused on EMD: • KPP risk management • TPM analyses and monitoring • Risk burn-down and closure rates • Cost growth monitoring EMD schedule monitoring (e.g., IMS model measurements for schedule slips) Affordability monitoring Continuous should cost estimation
P&D	Risk Management as an element of operational test and evaluation, production, and IOC	P&D Risk Management processes, procedures, and plan Special emphasis: P&D SCRM P&D risk management plan that includes addressing the above focus areas; include updates or refinements to the LCSP/ sustainment risk management, initially created as part of the program's overall EMD risk management plan	PM's Risk Management Dashboard focused on P&D • Funding streams • Continuity of production levels and frequency of breaks • Production failure rate, supplier quality non-conformances, and cost impact metrics • Impact of supplier and design changes to the qualified baseline Deployment and fielding schedules

Phase	Focus	Products / Outputs (Risk Considerations)	Measures / Metrics
O&S	Risk Management as an element of operational readiness and FOC	O&S Risk Management processes, procedures, and plan Special Emphasis: O&S SCRM O&S risk management plan that includes addressing the above focus areas	PM's Risk Management Dashboard focused on O&S: • O&S funding streams • Management and burn-down of technology obsolescence risks • Technology insertion upgrade schedules and refresh rate • Qualification and product verification of spares suppliers, field failure rates, and depot failure rates O&S contract monitoring

4.3.7. Configuration Management Process

4.3.7. Configuration Management Process

The Configuration Management process allows technical insight into all levels of the system design and is the principal methodology for establishing and maintaining consistency of a system's functional, performance, and physical attributes with its requirements, design, and operational information throughout the system's life cycle. Effective configuration management supports the establishment and maintenance of the product baseline, which enables the successful production, delivery, and sustainment of the needed capability to the end user.

Configuration Management activities support:

- Traceability of designs to requirements
- Proper identification and documentation of system elements, interfaces, and interdependencies
- Timely and thorough vetting and disposition
- Control and documentation of approved changes to baselines
- Proper and timely incorporation of verified changes in all affected items and documentation
- Consistent and appropriate provisions in the Engineering Change Proposal (ECP) and related contract actions
- Consistency between the product and its supporting documentation
- A complete audit trail of design decisions and modifications
- Continued assurance of system supportability and interoperability, consistent with

approved acquisition and life-cycle sustainment strategies

Configuration Management facilitates the orderly development of a system through establishment of the technical baseline (including the functional, allocated, and product baselines), and their assessment and approval at various technical reviews and audits. A baseline is an agreed upon description of the attributes of a product at a point in time, which serves as a basis for change. Upon approval, the baseline is placed under formal configuration control. Through Configuration Management, the program identifies, controls, and tracks changes to system baselines, ensuring changes occur only after thorough assessments of performance, cost, and schedule impacts and associated risks.

The following baselines are critical to executing Configuration Management:

- Functional Baseline: Describes the system's performance (functional, interoperability, and interface characteristics) and the verification required to demonstrate the achievement of those specified characteristics. It is directly traceable to the operational requirements contained in the Initial Capabilities Document (ICD). The Program Manager establishes Government control of the functional baseline at the System Functional Review (SFR) and verifies it through Functional Configuration Audits (FCA) leading up to the system-level FCA or the System Verification Review (SVR). Attributes of the functional baseline include:
    - Assessed to be achievable within cost and schedule constraints
    - Documentation of established interfaces between functional segments
    - Documented performance requirements traced to (draft) CDD requirements
    - Reflects design considerations and clear linkage in the systems of systems (SoS) context
    - Documented verification requirements
- Allocated Baseline: Describes the functional and interface characteristics for all system elements (allocated and derived from the higher-level product structure hierarchy) and the verification required to demonstrate achievement of those specified characteristics. The allocated baseline for each lower-level system element (hardware and software) is usually established and put under configuration control at the system element Preliminary Design Review (PDR). This process is repeated for each system element and culminates in the complete allocated baseline at the system-level PDR. The Program Manager then verifies the allocated baseline at the FCA and/or SVR. Attributes of the allocated baseline include:
    - All system-level functional performance requirements decomposed (or directly allocated) to lower-level specifications (configuration items (CI) for system elements)
    - Uniquely identified CIs for all system elements at the lowest level of the specification tree
    - All interfaces, both internal (between element CIs) and external (between the system under development and other systems), documented in interface control documents
    - Verification requirements to demonstrate achievement of all specified functional performance characteristics (element CI to element CI level and at the system

level) documented
    - Design constraints documented and incorporated into the design
- Product Baseline: Describes the detailed design for production, fielding/deployment, and operations and support. The product baseline prescribes all necessary physical (form, fit, and function) characteristics and selected functional characteristics designated for production acceptance testing and production test requirements. It is traceable to the system performance requirements contained in the Capability Development Document (CDD). The initial product baseline includes "build-to" specifications for hardware (product, process, material specifications, engineering drawings, and other related data) and software (software module design - "code-to" specifications). The initial system element product baseline is established and placed under configuration control at the system element Critical Design Review (CDR) and verified later at the Physical Configuration Audit. In accordance with DoDI 5000.02, the Program Manager assumes control of the initial product baseline for all Class I configuration changes at the completion of the system-level CDR to the extent that the competitive environment permits. This does not necessarily mean that the Program Manager takes delivery and acceptance of the Technical Data Package. Attributes of the product baseline include:
    - Requirements Traceability Matrix (RTM) is complete
    - The detailed design (hardware and software), including interface descriptions, satisfies the CDD or any available draft Capability Production Document (CPD), and pertinent design considerations
    - Hardware, software and interface documentation are complete
    - Key product characteristics having the most impact on system performance, assembly, cost, reliability, ESOH, and sustainment have been identified
    - Traceability from design documentation to system and system element verification requirements and methods is complete
    - Manufacturing processes that affect the key characteristics have been identified, and capability to meet design tolerances has been determined

Activities and Products

The program office and developer share responsibility for planning, implementing, and overseeing the Configuration Management process and its supporting activities. The distribution of responsibilities between the program office and the developer varies based on the acquisition strategy and the life-cycle phase.

The Program Manager approves the Configuration Management Plan and should ensure adequate resources are allocated for implementing Configuration Management throughout the life cycle. The Program Manager approves the system baselines, and approves Class I changes to the product baseline after CDR, usually through a Configuration Control Board (CCB). MIL-HDBK-61A, "Configuration Management Guidance" defines Class I and II changes:

- Class I changes impact the form, fit, function, or interface characteristics of the configuration item
- Class II changes are changes to a Government approved technical baseline that do not

meet the definition of a Class I change

In performance-based acquisition, these terms apply only to changes that affect Government-approved (baselined) configuration documentation.

The Systems Engineer ensures Configuration Management planning is complete, and should document details and activities in the program's Systems Engineering Plan (SEP) and the supporting Configuration Management Plan (CMP) (as appropriate). The CM process described in the DoD-adopted standard, ANSI/EIA-649-B-2011 "Configuration Management Standard," consists of five interrelated functions that, when collectively applied, allow the program to maintain consistency between product configuration information and the product throughout its life cycle. The five CM functions are:

- Configuration Management Planning and Management
- Configuration Identification
- Configuration Change Management
- Configuration Status Accounting
- Configuration Verification and Audit

4.3.8. Technical Data Management Process

4.3.8. Technical Data Management Process

Through the Technical Data Management process, the program identifies, acquires, manages, maintains, and ensures access to the technical data and computer software required to manage and support a system throughout the acquisition life cycle. Key Technical Data Management considerations include understanding and protecting Government intellectual property and data rights, achieving competition goals, maximizing options for product support, and enabling performance of downstream life-cycle functions. DoDI 5000.02 contains Technical Data Management requirements for Acquisition Category (ACAT) I and II programs.

Effective acquisition, upgrades, and management of product data provide:

- Information necessary to understand and evaluate system designs throughout the life cycle
- Ability to operate and sustain weapon systems under a variety of changing technical, operational, and programmatic environments
- Ability to re-compete item acquisition, upgrades, and sustainment activities in the interest of achieving cost savings; the lack of product data and/or data rights often makes it difficult or impossible to award contracts to anyone other than the original manufacturer, thereby taking away much or all of the Government's ability to reduce total ownership costs (TOC)

Activities and Products

The Program Manager and Systems Engineer, in conjunction with the Product Support Manager,

should ensure that life-cycle requirements for weapon system-related data products and data rights are identified early and that appropriate contract provisions are put in place to enable deliveries of these products. Figure 4.3.8.F1 shows the activities associated with Technical Data Management, including:

- Identify Data Requirements

- Formulate the program's Technical Data Rights Strategy (TDRS) and technical data management approach, with emphasis on technical and product data needed to support the product throughout its life cycle. (see DAG Chapter 2 Program Strategies for more information about Data Rights).
- Ensure that data requirements are documented in the TDRS; summarized in the Technology Development Strategy (TDS), Acquisition Strategy (AS), and Life-Cycle Sustainment Plan (LCSP) ; and submitted at each milestone prior to award of the contract for the next life-cycle phase.
- Consider not only the immediate, short-term costs of acquiring the needed technical data and data rights but also the long-term cost savings resulting from the ability to compete production and logistics support activities and reduce TOC. Understand that the Government can possess either Government Purpose or Unlimited Rights to use many types of technical data and data rights, at no additional cost, based on the type of technical data and the source of funding used to generate the data (see DoD Open Systems Architecture Contract Guidebook for Program Managers for more information about data rights).

- Acquire Data

- Use explicit contract Statement of Work tasks to require the developer to perform the work that generates the required data. The content, format, and quality requirements should be specified in the contract.
- Use current, approved Data Item Descriptions (DID) and Contract Data Requirements Lists (CDRL) in each contract to order the delivery of the required technical data and computer software.

- Receive, Verify, and Accept Data

- Ensure verification of content, format, and quality of all required product-related data received from originators.
- Inspect contractually ordered data deliverables to ensure markings are in accordance with the relevant data rights agreements and DFARS clauses, and contain appropriate distribution statements and/or export control statements.

Caution: *Acceptance of delivered data not marked consistent with the contract can result in the Government "losing" legitimate rights to technical data and can incur significant legal liability on the Government and the individual Government employees. Regaining those rights generally requires costly and time-consuming legal actions.*

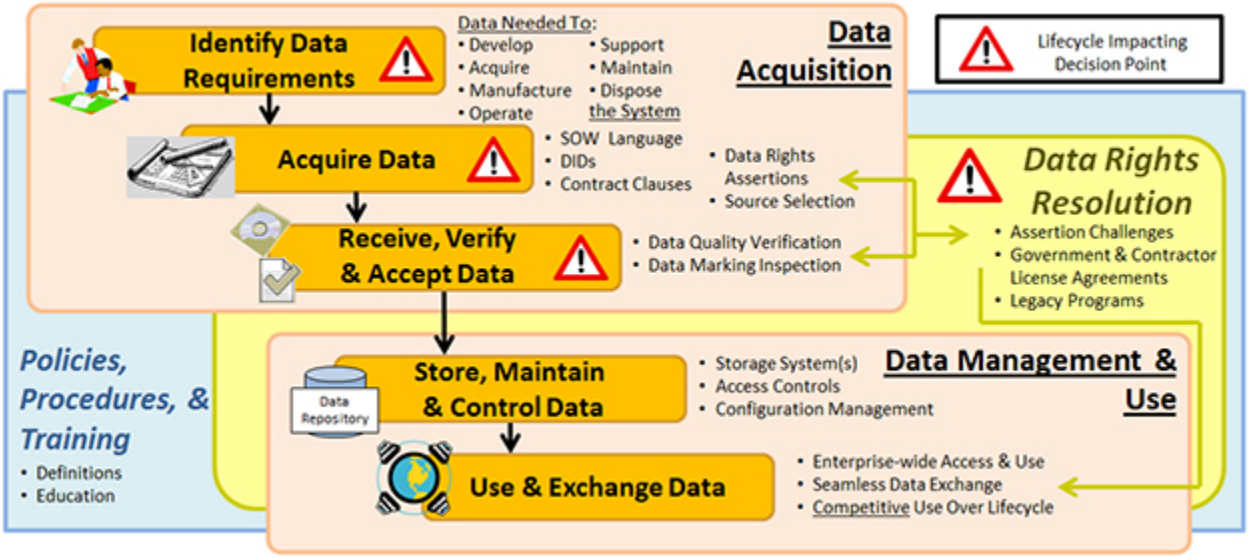
- Store, Maintain, and Control Data

- Budget for and fund the maintenance and upkeep of product data throughout the life cycle.
- An Integrated Data Environment (IDE) or Product Life-cycle Management (PLM) system allows every activity involved with the program to create, store, access, manipulate, and exchange digital data.
- To the greatest extent practical, programs should use existing IDE/PLM infrastructure such as repositories operated by Commodity Commands and other organizations. (Program-unique IDEs are discouraged because the high infrastructure cost; further, multiple IDEs inhibit access, sharing, and reuse of data across programs.)
- Ensure all changes to the data are made in a timely manner and are documented in the program IDE or PLM system.

- Use and Exchange Data

Plan for and establish methods for access and reuse of product data by all personnel and organizations that perform life-cycle support activities.

Figure 4.3.8.F1. Data Management Activities



In support of the Government's requirement for a Technical Data Package (TDP), the Program Manager should also consider all product related data (e.g., technical manuals, repair instructions, and design/analysis data) to:

- Allow logistics support activities
- Better enable sustainment engineering
- Apply, implement and manage product upgrades

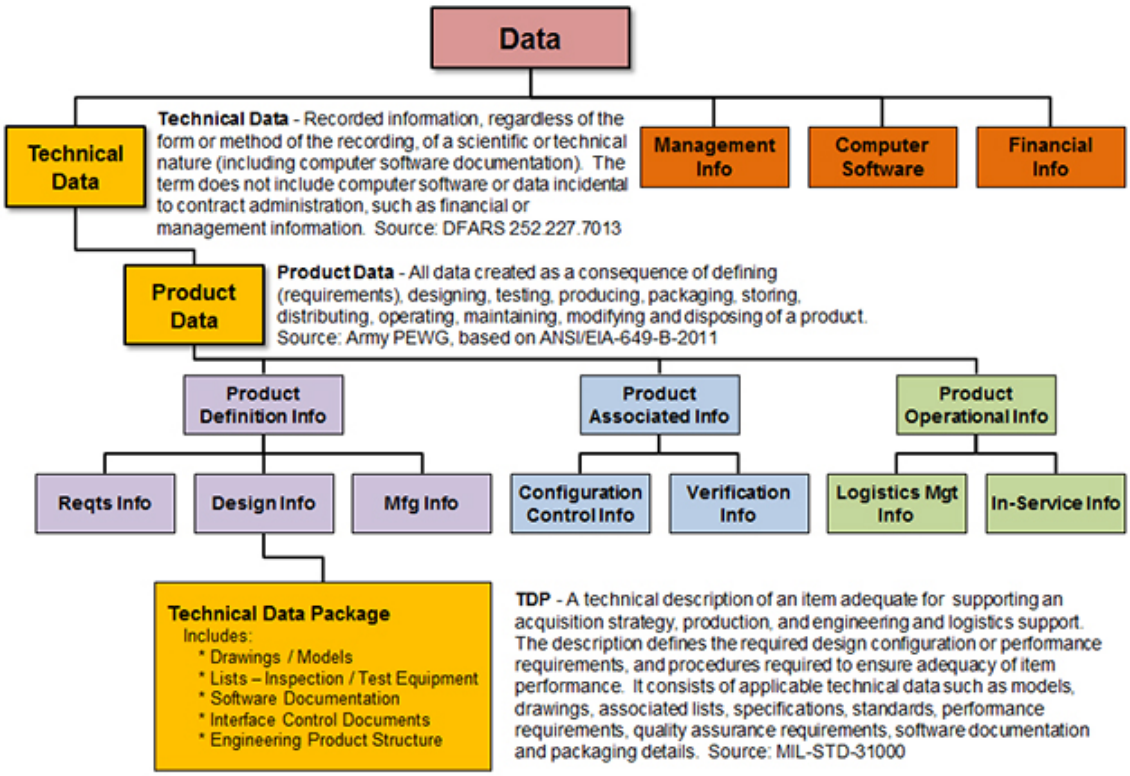
Contractually deliverable data should be identified and ordered at the specific "data product" level, e.g., two-dimensional drawings, three-dimensional Computer-Aided Design (CAD) models, technical manuals, etc. Figure 4.3.8.F2 provides a notional representation of different types of product-related data.

Caution: *Program Managers and Systems Engineers should be aware that terms such as "technical data," "product data," and "TDP" are imprecise, not equivalent, and often incorrectly used interchangeably.*

Resources for establishing and conducting Technical Data Management activities include but are not limited to:

- DoD 5010.12-M, Procedures for the Acquisition and Management of Technical Data
- Army Data Management Strategy (DMS) Guide and Addendum
- Air Force Product Data Acquisition (PDAQ) guidance
- Air Force Technical Data and Computer Software Rights Handbook
- Navy Technical Manual SL150-AA-PRO-010/DMP - Data Management Program
- MIL-HDBK-245, Handbook for the Preparation of Statement of Work
- MIL-STD-963, Data Item Descriptions
- MIL-STD-31000, Technical Data Packages

Figure 4.3.8.F2. Data Taxonomy



- Data Protection

The Program Manager is responsible for protecting system data, whether the data is stored and managed by the Government or by contractors. The DoD policy with regard to data protection, marking, and release can be found in:

- DoDD 5230.25
- DoDI 5230.24
- DoD 5400.7-R
- DoD 5200.1-M

Data containing information subject to restrictions are protected in accordance with the appropriate guidance, contract, or agreement. Guidance on distribution statements, restrictive markings, and restrictions on use, release, or disclosure, of data can be found in the DFARS Part 252.227-7013 and 7014, and DoDI 5230.24.

When digital data is used, the data should display applicable restriction markings, legends, and distribution statements clearly visible when the data is first opened or accessed. These safeguards not only ensure Government compliance regarding the use of data but also guarantee and safeguard contractor data delivered to the Government, and extend responsibilities of data handling and use to parties who subsequently use the data.

Section 208 of Public Law 107-347 and DoD Privacy Impact Assessment (PIA) guidance requires that PIA be conducted prior to developing or purchasing any DoD information system that collect, maintain, use, or disseminate personally identifiable information about members of the public, federal personnel, DoD contractors and, in some cases, foreign nationals. Available PIA guidance provides procedures for completing and approving PIAs. For further information, see DAG Chapter 7 Acquiring Information Technology, Including National Security Systems.

All data deliverables should include distribution statements. Processes should be established to protect all data that contain critical technology information, as well as ensure that limited distribution data, intellectual property data, or proprietary data is properly handled throughout the life cycle, whether the data are in hard-copy or digital format.

4.3.9. Interface Management Process

4.3.9. Interface Management Process

The Interface Management process assists the Program Manager ensure interface definition and compliance among the system elements, as well as with other systems. The Interface Management process helps ensure that developers document all internal and external interface requirements and requirements changes in accordance with the program's Configuration Management Plan. Developers also should communicate interface information to their counterparts responsible for affected systems and system elements, and should plan for coherent testing to verify expected performance and ultimately operational performance.

Systems are composed of system elements, and may operate as part of larger systems of systems (SoS). The design, definition and management of the physical and logical interfaces, both internal (communications between system elements) and external (communications between the system and other systems), are critical to program success. Both types of interfaces have become increasingly important as system complexity has increased, along with demands for systems to operate in highly interdependent SoS environments (see DAG section 4.2.1.2. Systems of Systems). Interfaces play a critical role in all systems and systems of systems that interact to deliver a collective capability. Complex systems consist of numerous interfaces of various types. In the absence of effective governance, interface sprawl can result in degraded system performance, sustainability, and maintainability.

Explicit management of the definition, development, implementation, and test of internal and external interfaces, including any associated dependencies, helps ensure that systems operate as designed and meet stakeholder expectations throughout the life cycle. Interface management should consider programmatic issues (e.g., roles and responsibilities, funding, scheduling) in addition to the technical aspects of systems engineering (SE) and integration.

Activities and Products

Interface management is an iterative process: as knowledge of the system and system elements increases during design activities, verifiable lower-level requirements and interfaces are defined and refined. Developers should assess impacts of the originally defined capabilities and interfaces, performance parameter thresholds and objectives, and the overall system when defining and modifying interfaces.

The Program Manager and Systems Engineer should ensure that the program's interface management plan:

- Documents the system's internal and external interfaces and their requirement specifications
- Identifies preferred and discretionary interface standards and their profiles
- Provides justification for selection and procedure for upgrading interface standards
- Describes the certifications and tests applicable to each interface or standard
- Is consistent with the program's configuration management plan

The Program Manager and Systems Engineer should ensure that the developer documents all system interface requirements (see DAG section 4.3.5. Requirements Management Process), places them under appropriate levels of configuration management, and makes them available to the appropriate stakeholders. These documented interface requirements serve critical functions at all levels of the system throughout the life cycle, including:

- Developing functional and physical architectures
- Facilitating competitive bids
- Enabling integration of systems and lower-level system elements
- Supporting system maintenance, future enhancements, and upgrades

- Providing input data for continuous risk management efforts

The Systems Engineer responsible for interface management has numerous key tasks throughout the life cycle, including:

- Defining and establishing interface specifications
- Assessing compliance of interfaces among configuration items composing systems or SoS
- Monitoring the viability and integrity of interfaces within a system
- Establishing an interface management plan to assess existing and emerging interface standards and profiles, to update interfaces, and to abandon obsolete architectures

The Program Manager should establish an Interface Control Working Group (ICWG) composed of appropriate technical representatives from the interfacing activities and other interested participating organizations. The ICWG serves as a forum to develop and provide interface requirements, as well as to focus on detail interface definition and timely resolution of issues. In the SoS environment, external program offices and developers collaborate as members of the ICWG.

4.3.10. Stakeholder Requirements Definition Process

4.3.10. Stakeholder Requirements Definition Process

During the Stakeholder Requirements Definition process, the lead Service, Component, or designated program office receives requirements from relevant stakeholders and translates them into a set of technical requirements. The process helps ensure each individual stakeholder's requirements, expectations, and perceived constraints are understood from the acquisition perspective. Failing to perform an exhaustive Stakeholder Requirements Definition process could result in significant requirements creep, rework due to misunderstanding of end-user needs, unexpected contract modifications, cost growth, and schedule slip. The objective of this process is to help ensure that stakeholder requirements are feasible, balanced, and fully integrated as more information is learned through requirements analysis.

Stakeholder Requirements Definition bridges the gap between the identification of a materiel need, described in the Joint Capabilities Integration and Development System (JCIDS) CJCSI 3170.01, and the acquisition of a materiel solution, governed by the Defense Acquisition System, i.e., DoDD 5000.01 and DoDI 5000.02.

The Stakeholder Requirements Definition process complements Requirements Analysis and Architecture Design (see DAG sections 4.3.11 Requirements Analysis Process and 4.3.12 Architecture Design Process, respectively). These three processes are recursively applied at each level of the system's specifications and then iteratively within each level throughout development.

The DoD Architecture Framework (DoDAF) provides an approach for DoD architecture development, presentation, and integration for both warfighting operations and business

operations and processes. For the Net Ready Key Performance Parameter (NR-KPP), JCIDS and CJCSI 6212.01 specify the data needed to elaborate, communicate, verify, and validate a system's interoperability requirements and design. System architectural descriptions contain three basic viewpoints: operational, system, and standards (or technical) viewpoints. In the case of the NR-KPP, these viewpoints contain essential architecture data that describe a system's interoperability requirements and design from multiple perspectives. DoDAF provides a standardized approach for capturing and presenting this architectural data. This standardization facilitates improved communication and sharing of technical information among various stakeholders and across organizational boundaries.

The Program Manager and Systems Engineer are responsible for supporting the Stakeholder Requirements Definition process and should work with the end user to establish and refine operational needs, attributes, performance parameters, and constraints documented in JCIDS documents.

Stakeholder Requirements Definition activities are performed throughout the acquisition life cycle and include the following activities:

- Elicit stakeholder capability objectives
    - Identify stakeholders who have an interest in the system and maintain relationships with the stakeholders and their organizations throughout the system's entire life cycle
    - Elicit capability objectives from the stakeholders about what the system will accomplish and how well
- Define stakeholder requirements
    - Define the perceived constraints on a system solution
    - Define the relevant environment and support scenarios that can be used to analyze the operation of the system
    - Define potential requirements that may not have been formally specified by any of the stakeholders
- Analyze and maintain stakeholder requirements
    - Analyze requirements for specificity, completeness, consistency, measurability, testability, and feasibility
    - Negotiate modifications with stakeholders to resolve requirement discrepancies
    - Validate, record, and maintain stakeholder requirements throughout the system life cycle
    - Support the Requirements Analysis process to establish and maintain a traceability matrix to document how the system requirements are intended to meet the stakeholder objectives and achieve stakeholder agreements

The authoritative source for stakeholder requirements are documents produced via the JCIDS such as the Initial Capabilities Document (ICD), Capability Development Document (CDD), and the Capability Production Document (CPD). JCIDS analyzes gaps in existing and/or future warfighting operations and provides a process that allows the Joint Requirements Oversight Council to balance joint equities and make informed decisions on validation and prioritization of

capability needs.

4.3.11. Requirements Analysis Process

4.3.11. Requirements Analysis Process

The Requirements Analysis process involves the decomposition of user needs (usually identified in operational terms at the system level during implementation of the Stakeholder Requirements Definition process; see DAG section 4.3.10 Stakeholder Requirements Definition Process) into clear, achievable, and verifiable high-level requirements. As the system design evolves, Requirements Analysis activities support allocation and derivation of requirements down to the system elements representing the lowest level of the design. The allocated requirements form the basis of contracting language and the system performance specification. The resultant system requirements are addressed at technical reviews and audits throughout the acquisition life cycle and in applicable program and systems engineering (SE) technical documentation.

The Requirements Analysis process objectives include:

- Define a capability that links the needs of the users to the system, system elements, and enabling system elements to be designed and developed
- Define a system that meets users' operational mission requirements within specified cost and schedule constraints
- Provide insight into the interactions among various functions to achieve a set of balanced requirements based on user objectives

The Requirements Analysis process provides:

- Translation of user needs (usually stated in operational terms) to unambiguous, verifiable, and feasible system performance specification requirements
- Incorporation of design considerations including statutory and regulatory constraints (see DAG section 4.3.18. Design Considerations)
- Documented allocation of requirements from the system-level specification to the lowest-level system elements and enabling system elements
- Rationale for specification requirements and their decomposition / allocation
- A mechanism to support trade-off analyses between related requirements to provide maximized mission assurance within cost and schedule constraints
- A framework for accurate assessment of system performance throughout the life cycle

The process of defining, deriving, and refining requirements proceeds as follows:

- Analyze user requirements
- Translate user needs into basic functions
- Develop a quantifiable set of performance requirements by defining the functional boundaries of the system in terms of the behavior and properties to be provided
- Define each function that the system is required to perform
- Define implementation constraints (stakeholder requirements or solution limitations)

- Translate performance requirements into specific system technical design requirements and functions

The Requirements Analysis process is an iterative activity whereby system requirements are identified, refined, analyzed, and traded to remove deficiencies and minimize impacts of potential cost drivers to establish an agreed-to set of requirements coordinated with the appropriate stakeholders. Poorly written requirements can lead to significant problems in the areas of schedule, cost, or performance, and can thus increase program risk. A well-crafted set of functional/performance requirements can then be translated into design requirements for the total system over its life cycle and can allow stakeholders to assess system performance during execution of the Verification and Validation processes (see DAG sections 4.3.15. Verification Process and 4.3.16. Validation Process, respectively). Good requirements have the following attributes:

- Necessary
- Unique
- Unambiguous - clear and concise
- Complete
- Consistent
- Technically feasible/achievable/obtainable
- Traceable
- Measurable/quantifiable
- Verifiable (e.g., Testable)
- Able to be validated
- Operationally effective
- Singular

The Requirements Analysis process ensures that requirements derived from user-specified capability needs are analyzed, decomposed, and functionally detailed across the system design. Early development and definition of requirements using the attributes listed above reduces development time, enables achievement of cost and schedule objectives, and increases the quality of the final system. Requirements Analysis encompasses the definition and refinement of the system, system elements, enabling system elements, and associated functional and performance requirements. The development of the functional baseline is largely a product of the Requirements Analysis process. All requirements are placed under configuration control, tracked, and managed as described in the Requirements Management process and Configuration Management process (see DAG sections 4.3.5. Requirements Management Process and 4.3.7. Configuration Management Process, respectively).

4.3.12. Architecture Design Process

4.3.12. Architecture Design Process

Architecture Design is a trade and synthesis process that allows the Program Manager and Systems Engineer to translate the outputs of the Stakeholder Requirements Definition and Requirements Analysis processes into alternative design solutions and establishes the

architectural design of candidate solutions that may be found in a system model. The alternative design solutions may include hardware, software, and human elements; their enabling system elements; and related internal and external interfaces. The Architecture Design process, combined with Stakeholder Requirements Definition and Requirements Analysis, provides key insights into technical risks early in the acquisition life cycle, allowing for early development of mitigation strategies. Architecture Design is integral to ensuring that multiple well-supported solutions are considered. The Architecture Design process supports analysis of design considerations and enables reasoning about key system aspects and attributes such as reliability, maintainability, survivability, sustainability, performance, and total ownership cost.

Architecture design synthesizes multiple potential solutions from system performance requirements, evaluates those solutions, and eventually describes the system down to the individual system element for implementation. The Architecture Design process is iterative and strives to seek a balance among cost, schedule, performance, and risk that still meets stakeholder needs.

The functional architecture provides the foundation for defining the system architecture through the allocation of functions and sub-functions to hardware/software, databases, facilities, and human operations to achieve its mission. The development of the physical architecture consists of one or more product structures or views of the physical solution. The product structure may consist of conceptual design drawings, schematics, and/or block diagrams that define the system's form and the arrangement of the system elements and associated interfaces. The DoD Architecture Framework (DoDAF) operational and system viewpoints provide one method for developing and describing the system functional architecture. The development of a physical architecture is an iterative and recursive process and evolves together with the functional requirements and functional architecture. Development of the physical architecture is complete when the system has been decomposed to the lowest system element (usually the lowest replaceable unit of the support strategy). It is critical that this process identify the design drivers and driving requirements as early as possible.

The Program Manager may oversee Architecture Design efforts to gain and maintain insights into program schedule and cost drivers for use in evaluation of alternative architectures, excursions, mitigation approaches, etc.

Key activities in the Architecture Design process include:

- Analysis and synthesis of the physical architecture and the appropriate allocation,
- Analysis of the constraint requirements,
- Identify and define physical interfaces and system elements, and
- Identify and define critical attributes of the physical system elements, including design budgets (e.g., weight, reliability) and open system principles.

During this process, derived requirements come from solution decisions. It is essential to identify derived requirements and ensure that they are traceable and part of the allocated requirements. For each given solution alternative, the Decision Analysis process trades off requirements against given solution alternatives. For each solution alternative, based on programmatic

decisions, certain performance requirements may be emphasized over others. The essence of this activity is to achieve a balanced and feasible design with acceptable risk, and that falls within the program design constraints. An integral part of defining and refining the functional and physical architecture is to provide technical support to the market research especially early in the acquisition life cycle. Systems engineers should analyze whether existing products (commercial or non-developmental items) can meet user performance requirements or whether technologies can realistically be matured within the required time frame. When possible, mature technologies should be used to satisfy user needs.

The development of the system architecture should adhere to sound systems engineering (SE) and should conform to industry standards as applicable. The functional architecture should be part of the functional baseline, and the physical architecture should be part of the allocated and product baselines. The system architecture should be placed under configuration control and maintained in a robust repository that maintains the architecture descriptions and its relationships to each of the baselines. This control provides the Systems Engineer with a means of ensuring consistency of the system architecture definition throughout the acquisition life cycle.

The output of this process is the system allocated baseline, which includes the documentation that describes the physical architecture of the system and the specifications that describe the functional and performance requirements for each configuration item along with the interfaces that compose the system. In addition, Work Breakdown Structures (WBS) and other technical planning documentation are updated. The system architecture and the resulting design documentation should be sufficiently detailed to allow the following:

- Confirmation of upward and downward traceability of requirements
- Confirmation of interoperability and open system performance requirements
- Sufficient product and process definition to support implementation, verification, and validation of the system
- Establishment of achievable alternatives to allow key stakeholders to make informed decisions

Confirmation of requirements traceability and the soundness of the selected physical architecture can be accomplished using a cost-effective combination of design modeling and analysis, as applicable.

The result of the Architecture Design process is an architectural design that meets the end-user capability needs shown in the Requirements Management process to have all stated and derived requirements allocated to lower level system elements and to have the possibility of meeting cost, schedule, and performance objectives. The architectural design should be able to be communicated to the customers and to the design engineers. The level of detail of the architectural design depends on the complexity of the system and the support strategy. It should be detailed enough to bound the cost and schedule of the delivered system, define the interfaces, ensure the customers that the requirements can be met, and control the design process down to the lowest removable unit to support operations and sustainment. This architecture design may be documented and found in a program's system model. Once identified, the system architecture

is placed under configuration management.

4.3.13. Implementation Process

4.3.13. Implementation Process

The Implementation process involves two primary efforts: design and realization. The outputs of the Implementation process include the detailed design down to the lowest level system elements in the system architecture, and the fabrication/production procedures of forming, joining, and finishing, or coding for software. Depending on technology maturity, the Implementation process may develop, buy, or reuse system elements to render the system. Implementation is integral to systematically increasing maturity, reducing risk, and ensuring the system is ready for Integration, Verification, and Validation. The Implementation process provides a system that satisfies specified design and stakeholder performance requirements. As a best practice, the Systems Engineer should develop an implementation plan including implementation procedures, fabrication processes, tools and equipment, implementation tolerances, and verification uncertainties.

Design

Implementation begins in the Materiel Solution Analysis phase, where the Analysis of Alternatives informs whether the preferred materiel solution can be developed, bought, or reused. This analysis takes many forms, such as modeling and simulation, experiments, and prototypes through which competing systems can be assessed. Careful decisions regarding the design of system elements can enable the use of open (non-proprietary) standards and an open systems or modular approach that may allow for resiliency as well as reduce costs and promote competition during development, production, technology refresh, and life-cycle extension. Design activities may include:

- Identify and analyze the constraints that the technology and design and realization techniques impose on the design solution
- Develop design and implementation prototypes and solutions for the system elements
- Analyze candidate system element design and implementation solutions and conduct variability studies to identify conflicts and resolution alternatives to ensure system integrity
- Identify fabrication and quality procedures, and document design assumptions and decisions in the final system elements drawings or technical data package

Realization

Realization is the process of building the system elements using specified materials and fabrication and production tools/procedures identified during design. Early fabrication and production planning is critical for successful realization and delivery of the needed capability. System elements are built to the product baseline and should meet quality standards. Realization activities may include:

This document is an accurate representation of the content posted on the DAG website for this Chapter, as of the date of production listed on the cover. Please refer to the DAG website for the most up to date guidance at https://dag.dau.mil

- Obtain or acquire access to materials and tools required to build system elements
- Obtain external system elements as applicable
- Build system elements in accordance with implementation procedures, tolerances, and applicable ESOH, security, and privacy
- Determine system elements functionality against specified product quality characteristics
- Document fabrication and production issues and associated corrective actions
- Deliver implemented system elements for integration and subsequent verification

The output of the Implementation process is the physical system elements as identified in the product baseline, including fabrication and production methods.

4.3.14. Integration Process

4.3.14. Integration Process

The program uses the Integration process to systematically assemble lower-level system elements into successively higher-level system elements, iterative with verification until the system itself emerges. Integration is essential to increasing system maturity, reducing risk, and preparing the system for transition to the warfighter.

The Interface Management process is critical to the success of the Integration process. Interface control specifications should be confirmed early on and placed under strict configuration control. All of the program's external interfaces and dependencies should be documented in the program's Systems Engineering Plan (SEP). The SEP Outline requires that all programs with external dependencies and/or interfaces establish Memoranda of Agreement (MOA) in order to formally establish commitments and management procedures. A current table showing the status of all MOAs is a mandated as part of the program SEP, which is updated in each phase.

The Program Manager and Systems Engineer are responsible for planning, managing, and executing the Integration process. Experience has shown that programs that develop an integration plan are more successful. This plan defines the stages of integration during which system elements are successively integrated to form higher level elements and eventually the finished product. Alternative integration paths should be considered. The integration plan should include a description of the required Systems Integration Laboratories or other facilities, personnel, test stands, harnesses, testing software, and integration schedule.

Integration activities support the Interface Management process by verifying that accurate and effective interface specifications are documented. In parallel, the verification methods for each integration level are developed and included in the allocated baseline. The successive integration phases follow the sequence defined in the program's integration plan and lead to the final product ready for verification and validation.

4.3.15. Verification Process

4.3.15. Verification Process

Verification provides evidence that the system or system element performs its intended functions and meets all performance requirements listed in the system performance specification and functional and allocated baselines. Verification answers the question, "Did you build the system correctly?" Verification is a key risk-reduction activity in the implementation and integration of a system and enables the program to catch defects in system elements before integration at the next level, thereby preventing costly troubleshooting and rework.

The Program Manager and Systems Engineer manage verification activities and methods as defined in the functional and allocated baselines, and review the results of verification. Guidance for managing and coordinating integrated testing activities can be found in DAG Chapter 9 Test and Evaluation and in DoDI 5000.02.

Verification begins during Requirements Analysis, when top-level stakeholder performance requirements are decomposed and eventually allocated to system elements in the initial system performance specification and interface control specifications. During this process, the program determines how and when each requirement should be verified, the tasks required to do so, as well as the necessary resources (i.e., test equipment, range time, personnel, etc.). The resulting verification matrix and supporting documentation become part of the program's functional and allocated baselines.

Verification may be accomplished by any combination of the following methods:

- **Demonstration.** Demonstration is the performance of operations at the system or system element level where visual observations are the primary means of verification. Demonstration is used when quantitative assurance is not required for verification of the requirements.
- **Examination.** Visual inspection of equipment and evaluation of drawings and other pertinent design data and processes should be used to verify conformance with characteristics such as physical, material, part, and product marking and workmanship.
- **Analysis.** Analysis is the use of recognized analytic techniques (including computer models) to interpret or explain the behavior/performance of the system element. Analysis of test data or review and analysis of design data should be used as appropriate to verify requirements.
- **Test.** Test is an activity designed to provide data on functional features and equipment operation under fully controlled and traceable conditions. The data are subsequently used to evaluate quantitative characteristics.

Designs are verified at all levels of the physical architecture through a cost-effective combination of these methods, all of which can be aided by modeling and simulation.

Verification activities and results are documented among the artifacts for Functional Configuration Audits (FCA) and the System Verification Review (SVR) (see DAG section 4.2.14. Functional Configuration Audits/System Verification Review). When possible, verification should stress the system, or system elements, under realistic conditions representative of its intended use.

The individual system elements provided by the Implementation process are verified through developmental test and evaluation (DT&E), acceptance testing, or qualification testing. During the Integration process, the successively higher level system elements may be verified before they move on to the next level of integration. Verification of the system as a whole occurs when integration is complete. As design changes occur, each change should be assessed for potential impact to the qualified baseline. This may include a need to repeat portions of verification in order to mitigate risk of performance degradation.

The output of the Verification process is a verified production-representative article with documentation to support Initial Operational Test and Evaluation (IOT&E). The SVR provides a determination of the extent to which the system meets the system performance specification.

4.3.16. Validation Process

4.3.16. Validation Process

Validation provides objective evidence that the capability provided by the system complies with stakeholder performance requirements, achieving its use in its intended operational environment. Validation answers the question, "Is it the right solution to the problem?" Validation consists of evaluating the operational effectiveness, operational suitability, sustainability, and survivability of the system or system elements under operationally realistic conditions.

The Program Manager and Systems Engineer are responsible for supporting the Validation process. The execution of the Validation process is typically conducted by independent testers as documented in the Test and Evaluation Master Plan (TEMP). System end users and other stakeholders are typically involved in validation activities. Guidance for managing and coordinating integrated testing activities can be found in DAG Chapter 9 Test and Evaluation and DoDI 5000.02. Using and engaging integrated test teams, composed of knowledgeable and experienced Government and industry developmental and operational testers, bring different perspectives and allow for an efficient use of resources.

Validation activities can be conducted in the intended operational environment or on an approved simulated environment. Early program-validation activities assist in the production of validated concept of operations (CONOPS), system performance specifications, use cases, functional and physical system architectures, and test cases. Validation is applied to the initial product baseline to ensure the emerging design meets the end-user needs. Models, simulations, mockups, and prototypes may be used in these early activities. They are often combined with the verification activities (see DAG section 4.3.15. Verification Process). Aggressive early validation significantly mitigates the risk to the program by identifying operational issues up front when they are easier and less costly to fix. This ultimately improves system performance during the final validation activity (e.g., operational test and evaluation (OT&E)).

Final validation involves operational testing on a production-representative system in an operationally realistic environment. The product of the Validation process is a validated system and enabling system elements, leading to approval for Full-Rate Production (FRP) and/or a Full Deployment (FD) Decision Review (DR).

4.3.17. Transition Process

4.3.17. Transition Process

Transition is the process applied to move any system element to the next level in the physical architecture. For the end-item system, it is the process to install and field the system to the user in the operational environment. The end-item system may need to be integrated with other systems in the operational environment honoring the defined external interfaces. In this case, the transition process needs to be performed in conjunction with the integration process and interface management process for a smooth transition.

Early planning for system transition reduces risk and supports smooth delivery and rapid acceptance by the system's end user. Transition considerations should include, as appropriate, user and maintainer requirements, training, deployability, support tasks, support equipment, and packaging, handling, storage, and transportation (PHS&T). Part of the Transition process is ensuring that each site is properly prepared for the receipt, acceptance, and/or installation of the system.

The Transition process includes maintenance and supportability activities for the deployed system and its enabling system elements, as well as a process for reporting and resolving deficiencies. The OUSD(AT&L) memorandum, "Document Streamlining - Life-Cycle Sustainment Plan (LCSP)" requires that sustainment and support planning be documented in the LCSP, which is required for all Major Defense Acquisition Programs and reviewed prior to Milestones A, B, and C, as well as the Full-Rate Production Decision Review (FRP DR).

The Program Manager, Systems Engineer, and Product Support Manager oversee all transition plans and activities required to install or deploy the end-item system and enabling system elements to its operational environment. The Systems Engineer conducts In-Service Reviews (see DAG section 4.2.17. In-Service Review) and leads all engineering efforts to correct deficiencies found during transition. Program Managers should ensure all deliverables, particularly documentation (i.e. drawings, tech manuals, etc.), have been received from the contractor.

Transition activities vary based on life-cycle phase, program scale, and system complexity. The end-item system may need to be integrated with other systems in the operational environment based on the defined external interfaces. In this case, the Transition process is performed in conjunction with the Integration process and Interface Management process for a smooth transition.

4.3.18. Design Considerations

4.3.18. Design Considerations

The program should review the requirements to determine conformance with Government policy and legal compliance and to identify potential integration and interoperability challenges. The Program Manager and Systems Engineer should consider and document all statutory and

regulatory as well as other design considerations in order to:

- Satisfy the unique needs of the program or system (user capabilities, and operational performance requirements) while balancing cost and schedule constraints, through trade-offs, by addressing the design considerations (as mandated in the Systems Engineering Plan (SEP) and DoDI 5000.02) and management tools listed in Table 4.3.18.T1 Design Considerations
- Translate the end user desired capabilities into a structured system of interrelated design specifications
- Enable trade-offs among the design considerations in support of achieving desired mission effectiveness within cost and schedule constraints
- Translate the end-user desired capabilities into a structured system of interrelated design specifications that support delivery of required operational capability
- Incorporate mandated design considerations into the requirements since some design considerations are mandated by laws, regulations, or treaties, while others are mandated by the domain or Service / Component; these mandates should be incorporated during the Requirements Analysis process to achieve balance across all of the system requirements

Some design considerations are concepts that assist trade-offs and ought to be accommodated or applied to each system/program/project. Others are constraints, boundaries, or limitations, with values that sometimes can be tailored or negotiated, but which in general represent fairly immovable parts of the trade space. The Program Managers and Systems Engineers should show evidence of critical thinking in addressing the design considerations, as documented in the program SEP. The mandated SEP Outline Table 4.6-1 identifies design considerations critical to achieving the program's technical requirements and demonstrates that the mandated design considerations are an integral part of the design decision process, including trade study criteria.

With the understanding that each design consideration is a discrete item to investigate during the design process, the Program Manager and Systems Engineer also need to view design considerations as an integrated set of variables. These variables influence one another, and stakeholders should consider them in conjunction with one another, as early as the Analysis of Alternatives, to achieve better mission performance and to preclude a stove pipe view during design.

The design considerations listed in Table 4.3.18.T1 need to be assessed for applicability to the system since they may not all be appropriate. Table 4.3.18.T1 is not all inclusive and does not include any additional design considerations levied by the Service, Center, platform, or domain. Not all design considerations are equally important or critical to a given program, but all should be examined for relevancy.

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Table 4.3.18.T1. Design Considerations

Design Consideration	DAG Section Number	Statutory Requirement	Policy & Guidance
Accessibility (Section 508 Compliance)	**4.3.18.1.**	• Section 508 of the Rehabilitation Act of 1973 (as amended 36 CFR Part 1194)	• DoDD 8000.01 • DoD 8400.01-M • FAR 39.204
Affordability - SE Trade-Off Analysis	**4.3.18.2.**		• USD(AT&L) memorandum, "Better Buying Power 2.0: Continuing the Pursuit for Greater Efficiency and Productivity in Defense Spending," November 13, 2012 • USD(AT&L) memorandum, "Implementation Directive for Better Buying Power-Restoring Affordability and Productivity in Defense Spending," November 3, 2010 • USD(AT&L) memorandum, "Better Buying Power: Guidance for Obtaining Greater Efficiency and Productivity in Defense Spending," September 14, 2010
Anti-Counterfeiting	**4.3.18.3.**	• FY2012 National Defense Authorization Act (NDAA)	• USD(AT&L) memorandum, "Overarching DoD Counterfeit Prevention Guidance," March 16, 2012
Commercial-Off-the-Shelf (COTS)	**4.3.18.4.**	• Sections 403 and 431 of title 41, United States Code • Public Law 103-355 • Public Law 104-106	• DoDI 5000.02, Enclosure 2
Corrosion Prevention and Control (CPC)	**4.3.18.5.**	• Section 2228 of title 10, United States Code	• DoDD 5000.01, Enclosure 1, paragraph E1.1.17 • DoDI 5000.02, Enclosure 12, paragraph 7 • DoDI 5000.67 • PDUSD(AT&L) memorandum, "Document Streamlining - Program Strategies and Systems Engineering Plan," April 20, 2011 • DoD Corrosion Prevention and Control Planning Guidebook • DFARS 223.73

Design Consideration	DAG Section Number	Statutory Requirement	Policy & Guidance
Critical Safety Item (CSI)	**4.3.18.6.**	• Section 802 of Public Law 108-136 • Section 130 of Public Law 109-364 • Section 2319 of title 10, United States Code	• DoD 4140.1-R • JACG Aviation CSI Management Handbook • SECNAVINST 4140.2 • AFI 20-106 • DA Pam 95-9 • DLAI 3200.4 • DCMA INST CSI (AV) Management of Aviation Critical Safety Items • DFARS 209.270, 246.407, 246.504, 246.371 and 252.246-7003
Demilitarization and Disposal	**4.3.18.7.**		• DoDI 4160.28, Volume 1 • DoDI 5000.02, Enclosure 2, paragraph 8.c.(2) • DoD 4140.1-R • DoD 4160.21-M • MIL-STD-882E
Diminishing Manufacturing Sources and Material Shortages (DMSMS)	**4.3.18.8.**		• SD-22
Environment, Safety, and Occupational Health (ESOH)	**4.3.18.9.**	• National Environmental Policy Act (NEPA) • Section 4321-4347 of title 42, United States Code • Executive Order 12114, Environmental Effects Abroad of Major Federal Actions	• DoDI 4715.9 • DoDI 5000.02, Enclosure 12 • PDUSD(AT&L) memorandum, "Document Streamlining - Program Strategies and Systems Engineering Plan," April 20, 2011 • MIL-STD-882E • DFARS 223.73 • FAR 23.2, 23.4, 23.7 and 23.8
Human Systems Integration (HSI)	**4.3.18.10.**		• DoDD 5000.01, Enclosure 1, paragraph E1.1.29 • DoDI 5000.02, Enclosure 8
Insensitive Munitions	**4.3.18.11.**	• Section 2389 of title 10, United States Code	• DoDD 6055.9 • Secretary of Defense Memorandum, "DoD Policy on Submunition Reliability," January 10, 2001 • USD(AT&L) Memorandum, "Joint Insensitive Munitions Test Standards and Compliance Assessment," February 10, 2010 • USD(AT&L) Memorandum, "Insensitive Munitions Strategic Plans," July 21, 2004 • DoD Acquisition Manager's Handbook for Insensitive Munitions, Revision 02, November 2008

Design Consideration	DAG Section Number	Statutory Requirement	Policy & Guidance
Intelligence (Life-cycle Mission Data Plan (LMDP))	**3.3.18.12.**		• DoDD 5250.01
Interoperability and Dependency (I&D)	**4.3.18.13.**	• Public Law 104-106 • Section 3506 of title 44, United States Code	• DoDD 4630.05 • DoDD 5000.01 • DoDI 2010.06 • DoDI 4630.8 • DoDI 5000.02 • CJCSI 3170.01 • CJCSI 6212.01 • JCIDS Manual
Item Unique Identification (IUID)	**4.3.18.14.**		• DoDD 8320.03 • DoDI 4151.19 • DoDI 4140.01 • DoDI 5000.02, Enclosure 12, paragraph 10 • DoDI 5000.64 • DoDI 8320.04 • PDUSD(AT&L) Memorandum, "Document Streamlining - Program Strategies and Systems Engineering Plan," April 20, 2011 • DoD Guide to Uniquely Identifying Items, Version 2.5, September 15, 2012 • DoD Guidelines for Engineering, Manufacturing and Maintenance Documentation Requirements, April 20, 2007 • DFARS 211.274-2, 252.211-7003, 252.211-7007
Open Systems Architecture (OSA)	**4.3.18.15.**	• Section 2430 of title 10, United States Code	• DoDI 5000.02, Enclosure 12, paragraph 8 • DoD 5010.12-M • USD(AT&L) Memorandum, "Better Buying Power 2.0: Continuing the Pursuit for Greater Efficiency and Productivity in Defense Spending," November 13, 2012
Operational Energy	**4.3.18.16.**	• Section 138c of title 10, United States Code	• CJCSI 3170.01 • JCIDS Manual
Packaging, Handling, Storage and Transportation (PHS&T)	**4.3.18.17.**	• Title 49 of the Code of Federal Regulations (49 CFR)	• DoDI 4540.07 • DoD 4145.19-R • DoD 4140.27-M • DTR 4500.9-R

Design Consideration	DAG Section Number	Statutory Requirement	Policy & Guidance
Producibility, Quality & Manufacturing (PQM)	**4.3.18.18.**	• Section 812 of National Defense Authorization Act FY2011	• DoDI 5000.02, Enclosure 2 • DFARS 207.105, 215.304
Reliability & Maintainability (R&M) Engineering	**4.3.18.19.**	• Public Law 111-23, Weapon System Acquisition Reform Act 2009	• DoDI 5000.02, Enclosure 12 • DTM 11-003 • PDUSD(AT&L) memorandum, "Document Streamlining - Program Strategies and Systems Engineering Plan," April 20, 2011 • DoD Reliability, Availability, Maintainability, and Cost Rationale (RAM-C) Report Manual
Spectrum Management	**4.3.18.20.**	• Sections 305 and 901 - 904 of title 47, United States Code • Section 104 of Public Law 102-538	• DoDD 3222.3 • DoDI 4650.01 • DoDI 5000.02, Enclosure 12, paragraph 11 • AR 5-12 • AFI 33-118 • OPNAVINST 2400.1 and 2400.2 • OPNAVINST 2400.20F
Standardization	**4.3.18.21.**	• Sections 2451-2457 of title 10, United States Code • Public Law 82-436	• DoDI 4120.24 • DoD 4120.24-M • SD-19
Supportability	**4.3.18.22.**		• DoDD 5000.01, Enclosure 1, paragraphs E1.1.17, E1.1.29 • DoDI 4151.22 • PDUSD(AT&L) Memorandum, "Document Streamlining - Life-Cycle Sustainment Plan (LCSP)," September 14, 2011 • DoD 4140.1-R • DoD 4151.22-M • SD-19 • MIL-HDBK-502
Survivability (including CBRN) & Susceptibility	**4.3.18.23.**		• DoDI 3150.09 • DoDI 5000.02, Enclosures 6 and 8

Design Consideration	DAG Section Number	Statutory Requirement	Policy & Guidance
System Security Engineering (SSE)	**4.3.18.24.**	• Section 2358 of title 10, United States Code	• DoDI 5000.02, Enclosure 4 • DoDI 5200.39 • DoDI 5200.44 • DODI 8500 Series • PDUSD(AT&L) memorandum, "Document Streamlining - Program Protection Plan (PPP)," July 18, 2011 • Program Protection Plan Outline and Guidance, Version 1.0, July 2011

4.3.18.1. Accessibility (Section 508 Compliance)

4.3.18.1. Accessibility (Section 508 Compliance)

All Electronic and Information Technology (E&IT) systems comply with Section 508 of the Rehabilitation Act (as amended 36 CFR Part 1194), unless exempt under FAR 39.204 as a military system or National Security System. Compliance with Section 508 provides access by Federal employees with disabilities and the public to information and data that able-bodied persons can access through E&IT systems. Section 508 should be considered as a design requirement, addressed at each technical review, and clearly stated in the Acquisition Strategy and Systems Engineering Plan.

Program Managers should ensure Section 508 compliance, unless exempt, while Systems Engineers are responsible for implementation through use of standards and compliant tools and products.

Resources to aid programs in complying are in Table 4.3.18.1.T1. Additional information on accessibility is found in DAG Chapter 6 Human Systems Integration and Chapter 7 Acquiring Information Technology, Including National Security Systems.

Table 4.3.18.1.T1. Links to Section 508 Government Resources

Description of Link	Active Link
Section 508 technical standards	http://www.access-board.gov/508.htm
Federal rules for Section 508 implementation hosted by GSA has: • Roles and responsibilities of procurement officials and engineers • 508 best practices • Products and techniques	http://www.section508.gov/index.cfm
The "Buy Accessible System" GSA site has free tools and guides for conduct of Section 508-compliant acquisitions as well as on-line training and help desk	http://www.buyaccessible.gov/ and section.508@gsa.gov help desk

Department of Health and Human Services has: • Check lists • Code library • Test tools	http://www.hhs.gov/ found by searching on "section 508"
Department of Justice home page for ADA has federal laws and pending legislation	http://www.ada.gov/
Department of Veteran Affairs reports on Section 508 products and tools and tracks user comments	http://www.section508.va.gov/

4.3.18.2. Affordability - Systems Engineering Trade-Off Analyses

4.3.18.2. Affordability - Systems Engineering Trade-Off Analyses

Affordability is the degree to which the capability benefits are worth the system's total life-cycle cost and support DoD strategic goals. Systems engineering (SE) trade-off analyses for affordability, a special application of the Decision Analysis process (see DAG section 4.3.3. Decision Analysis Process), supports the establishment of a realistic affordability target, serves as inputs for the will cost and should cost estimates, and enables continuous monitoring of affordability estimates across the system life cycle. SE trade-off analyses should always practice continuous improvement, value engineering and Lean Six Sigma.

Although not a mandated Key Performance Parameter (KPP), the affordability target is managed throughout the system life cycle as a system KPP and cannot be changed without Milestone Decision Authority (MDA) approval. The USD(AT&L) memorandum "Implementation Directive for Better Buying Power Restoring Affordability and Productivity in Defense Spending" requires the program to establish an affordability target at Milestone A. This affordability target forms the basis for the SE trade-offs and sensitivity analyses that is conducted in support of Milestone B, and subsequent reviews. The affordability target is nominally the average unit acquisition cost and average annual operations and support cost per unit. For indefinite quantity of production units, the affordability target may be the total acquisition cost (see DAG Chapter 3 Affordability and Life-Cycle Resource Estimates for more information regarding the affordability target).

The independently generated will cost estimate is used to defend the system budget but does not account for potential efficiencies. The should cost estimate is based on efficient use of resources and effective implementation of processes, and is the focus of SE activities and program management decisions across the life cycle.

The SE trade-offs are conducted among cost, schedule, and performance objectives to ensure the program is affordable. The Program Manager should identify the design performance points that are the focus of trade-off analyses to establish cost and schedule trade space. The Program Manager presents the results of the trade-off analyses at program milestone/technical reviews, showing how the affordability target varies as design performance and schedules are varied (affordability drivers) and demonstrating how the cost-effective design point is established for the program.

The Program Manager and Systems Engineer use the results of SE trade-off analyses for affordability to inform system requirements and ensure that, when taken collectively, the requirements are compelling, affordable, and achievable within the time frame available to the program. These requirements are normally characterized by creative alternatives, reliable information and models, well-reasoned aggregation techniques, and a sound recommendation and action plan.

The trade-off analyses are executed by a resourced team that consists of a decision maker with full responsibility, authority, and accountability for the trade at hand, a trade-off analyst with a suite of reasoning tools, subject matter experts with performance models, and a representative set of end users and other stakeholders.

Throughout the system life cycle, the Systems Engineer continuously monitors affordability drivers, identifies opportunities to reduce life-cycle costs, and conducts trade-off analyses as needed to meet program cost, schedule, and performance requirements.

4.3.18.3. Anti-Counterfeiting

4.3.18.3. Anti-Counterfeiting

An increasing threat of counterfeit (and fraudulent) parts in the global marketplace affects every component of the program from commercial-off-the-shelf (COTS) assemblies to military-unique systems. Preventing counterfeit parts from entering the supply chain reduces cost and negative impacts to program schedule and system performance. "Overarching DoD Counterfeit Prevention Guidance" policy memorandum was signed by USD(AT&L) on March 16, 2012.

Counterfeit parts are becoming pervasive in various supply chains and therefore have become a significant threat to the Defense supply chain. Counterfeiters motives are primarily greed (profit) and/or malicious intent. Counterfeits may appear at all phases of the life cycle, making it necessary for the Program Manager, Systems Engineer, and Product Support Manager to plan for prevention, detection, remediation, reporting, and restitution activities from the beginning of the life cycle to disposal and demilitarization.

Anti-counterfeit activities have relations, as describe in Table 4.3.18.3.T1, with many of the other design considerations outlined in DAG section 4.3.18. Design Considerations, such as:

Table 4.3.18.3.T1. Anti-Counterfeit Design Consideration Relationships

Design Consideration	Relationship
Commercial-Off-the-Shelf (COTS)	The Government and its industry agents have little to no visibility into the supply chains that create COTS products. Implications of this lack of visibility into the supply chain include counterfeit vulnerabilities and counterfeit parts being more readily available.

Design Consideration	Relationship
Corrosion Prevention and Control (CPC)	Counterfeits, by their nature, may have been falsely certified. In addition, if the counterfeit is a compound/material or component (e.g., gaskets, ground wires) intended to prevent or reduce corrosion, then effects of wear may appear sooner than predicted and the impacts to the system may be worse than expected or catastrophic.
Critical Safety Items (CSI)	From an anti-counterfeiting risk-based approach, CSI should be more carefully scrutinized to ensure no counterfeits infiltrate the supply chain.
Demilitarization and Disposal	An excellent source for counterfeiters to obtain parts that can be turned into "used sold as new" parts (fraudulently certified as new).
Diminishing Manufacturing Sources and Material Shortages (DMSMS)	As systems age and the trustworthy sources for the piece parts dry up, counterfeiters increasingly take advantage of the situation by offering a source for hard-to-find-parts.
Environment, Safety, and Occupational Health (ESOH)	Several examples of counterfeit materials that can increase ESOH risks include: false R-134, a refrigerant which produces explosive by-products; fire extinguishers compressed with air; and faulty smoke detectors. Furthermore, Restriction of Hazardous Substances (RoHS) (2002/95/EC) has led to increased numbers of counterfeits, where a lead-free (Pb-free) microcircuit is sold as having tin-lead (SnPb) leads.
Item Unique Identification (IUID)	Successful implementation of IUID could reduce the ability of counterfeiters to introduce parts into supply. Conversely, IUID may provide a false sense of security if it can be duplicated by counterfeiters.
Open Systems Architecture (OSA)	OSA could provide a means to quickly certify a newer, more available part for use in weapon systems, thus reducing the impact of DMSMS. Conversely, it could also result in more part numbers (equivalents) being introduced into supply thus increasing the likelihood of counterfeit intrusion.
Producibility, Quality, and Manufacturing (PQM)	PQM can be severely degraded if supply is contaminated with counterfeits.
Reliability and Maintainability Engineering	Counterfeits that somehow get past receipt inspection and test can have radically different reliability and failure modes than the "honest" part.
Supportability	Increased failure rates due to counterfeits can have a negative impact on supportability and might drive the wrong problem-resolution behaviors and increase sustainment costs.
System Security Engineering (SSE)	SSE implements anti-counterfeit protection measures as part of a comprehensive plan to protect CPI and mission-critical functions and components.

During development of the Systems Engineering Plan (SEP), the Program Manager, Systems Engineer, and Product Support Manager should consider these relationships and develop plans to address the threat.

4.3.18.4. Commercial-Off-the-Shelf

4.3.18.4. Commercial-Off-the-Shelf

The use of commercial-off-the-shelf (COTS) items, including Non-Developmental Items, can provide significant opportunities for efficiencies during system development but also can introduce certain issues that should be considered and mitigated if the program is to realize the expected benefits. Investigation of COTS product use is required by DoDI 5000.02, Enclosure 2.

The primary benefits of using COTS components in system design are to:

- Reduce development time
- Allow faster insertion of new technology
- Lower life-cycle costs by taking advantage of the more readily available and up-to-date commercial industrial base

However, regardless of the extent to which a system is made up of commercial items, the Program Manager still engineers, develops, integrates, tests, evaluates, delivers, sustains, and manages the overall system.

Among concerns with using COTS products are:

- Subtle differences in product use can significantly affect system effectiveness, ESOH, reliability, and durability
- If integration requires a "modified COTS product," meaning that a COTS product may not be designed for many military environments (which, by definition, is not a COTS product under section 403 of title 41, United States Code, but is allowed under section 431 of title 41, United States Code), then the program may lose the ability to use the vendor's subsequent product upgrades or to find a suitable replacement for the product from other commercial sources
- The vendors can embed proprietary functions into COTS, limiting supply sources
- Vendors do not have to provide design information and often restrict purchasers from reverse engineering their intellectual property
- Licensing agreements vary and can be very restrictive while limiting the vendors liability for merchantability for intended purposes
- Supply chain risk management of COTS items is limited by the vendor, who is under no obligation to the purchaser to provide such information
- Incorporating COTS products places constraints on the rest of the design and reduces trade space; functionality, interfaces, and reliability and maintainability characteristics are embedded in the choice of a COTS system element
- Difficulty in finding suitable replacements and/or alternate items if the COTS vendor stops manufacturing the product or changes the configuration drastically, requiring the need to maintain different configurations of a single product
- The program needs to understand the "pedigree" or the qualified vendors for the COTS product
- The graphical user interface (GUI) design may not completely support user tasks, which can cause inefficient workarounds and improper use of the system by the user

The marketplace drives COTS product definition, application, and evolution. COTS products presume a flexible architecture and often depend on product releases that are designed to be used "as is" to meet general business needs and not a specific organization's needs. The commercial product life cycle is usually much shorter than the equivalent military product life cycle. Programs should consider the potential availability of suitable replacement and/or alternative items throughout the longer, military life cycle, and should monitor the commercial marketplace through market research activities and ongoing alignment of business and technical processes. This necessary activity imposes additional cost, schedule, and performance risks that the acquisition community should plan for. COTS products should be evaluated to meet all performance and reliability requirements during all environmental conditions and service life requirements specified by the intended application requirements documents.

The Federal Acquisition Streamlining Act (FASA) of 1994 (Public Law 103-355) and the Clinger-Cohen Act (Public Law 104-106) both endorse the use of COTS products by the Federal Government but have slightly different definitions, with the latter allowing for modifications to COTS.

The Systems Engineer should ensure open system design, identification and mitigation of Environment, Safety, and Occupational Health (ESOH) and security risks, survivable technology insertion, or refresh throughout the projected system life cycle.

The Program Manager and Systems Engineer should consider the following when evaluating use of COTS products:

- The intended product use environment and the extent to which this environment differs from (or is similar to) the commercial use environment
- Integration, documentation, security, Human System Integration, ESOH, hardware/software integrity, reliability risk, operational environment, and corrosion susceptibility/risk, etc.
- Planning for life-cycle activities (including sustainment, supply chain risks, obsolescence, and disposal)
- Developing relationships with vendors, Foreign Ownership Control, and Influence (FOCI) (see Defense Security Service for the latest policy regarding COTS from FOCI sources)
- Supportability, if vendor or marketplace changes occur
- Test and evaluation of COTS items (including early identification of screening, functionality testing and usability assessments) (See DAG Chapter 9 Test and Evaluation, Chief Development Tester)
- Protecting intellectual property rights by being aware of pertinent intellectual property right issues associated with commercial items acquisitions, especially with the acquisition of commercial software products. When acquiring Intellectual Property (IP) license rights, the acquisition community should consider the core principles described in the DoD guide: "Intellectual Property: Navigating through Commercial Waters."
- Ability to modify or interface COTS software with other software even if Government generated or owned
- Ability to have insight into configuration management, and the features and functions of

upgrades and changes
- Ability to instrument and/or test aspects of COTS products

4.3.18.5. Corrosion Prevention and Control

4.3.18.5. Corrosion Prevention and Control

The corrosion of military equipment and infrastructure within the DoD has been documented to cost approximately $23 billion annually. In addition to its significant financial impact, corrosion can also adversely affect system availability and ESOH. Therefore, it is extremely important to plan for and implement corrosion prevention and mitigation as early as possible in the acquisition life cycle (even prior to Milestone A) to minimize the life-cycle impact.

The execution of a program's Corrosion Prevention and Control (CPC) planning should contribute to reduced corrosion vulnerability with lower life-cycle costs; and improved ESOH, maintainability, and availability.

Section 2228 of title 10, United States Code requires planning and execution of corrosion prevention and mitigation in DoD systems. Accordingly DoDI 5000.02 and 5000.67 require corrosion prevention and control planning for all acquisition programs across the life cycle. Elements of good CPC engineering include, but are not limited to, the following:

- Examination of legacy systems for possible corrosion design improvements
- Open and transparent assessment of alternative materials and processes that offer increased protection against corrosion
- Inclusion of CPC as a consideration in trade studies involving cost, useful service life, and effectiveness
- Incorporation of CPC criteria into relevant contractual documentation
- Identification, planning, resourcing, and acquisition of corrosion-related features for longevity, lowest total ownership cost (TOC), and maximum of effectiveness in support of the program

In the PDUSD(AT&L) memorandum, "Document Streamlining - Program Strategies and Systems Engineering Plan," April 20, 2011, Program Managers are directed to capture all design considerations relating to CPC planning within the Systems Engineering Plan (SEP) with "hotlinks" to the program's CPC Plan.

The Program Manager is responsible for ensuring resources, including corrosion engineering expertise, are available throughout the program and that corrosion performance is considered appropriately during design trades. The Systems Engineer, supported by CPC subject matter experts, is responsible for identifying corrosion concerns and developing mitigation strategies within the whole system design and operational construct.

All designated Acquisition Category (ACAT) programs are required to accomplish CPC planning across their life cycle, with ACAT I programs required to formally document this planning in an approved CPC Plan delivered at Milestones B and C. In addition, the DoD has

developed the Corrosion Prevention and Control Planning Guidebook as a resource to assist the Program Manager, Systems Engineers, and other program staff in the development of a robust CPC program.

For all ACAT programs, CPC engineering should be reflected in various program documents, including, but not limited to:

- Technology Development Strategy/Acquisition Strategy (TDS/AS)
- SEP
- Test and Evaluation Master Plan (TEMP)
- Life-Cycle Sustainment Plan (LCSP)
- Contract/Request for Proposal (RFP)
- Program schedule - Integrated Master Plan/Integrated Master Schedule (IMP/IMS)
- Funding/budget
- Programmatic ESOH Evaluation (i.e., DFARS Subpart 223.73, Minimizing the Use of Hexavalent Chromium)
- System finish/process specification (add as a Data Item Description (DID) to Contract Data Requirements List (CDRL))
- System Performance Specification design, build, and testing requirements

In the contract and RFP, CPC planning should be addressed in some fashion in the technical content of each contract/RFP Section and subsection, including, but not limited to the Statement of Work (SOW), IMP/IMS, CDRL, and system performance specification (see DAG section 4.1.6. SE Role in Contracting).

4.3.18.6. Critical Safety Item

4.3.18.6. Critical Safety Item

Critical Safety Item (CSI) is a part, assembly, or support equipment whose failure could cause loss of life, permanent disability or major injury, loss of a system, or significant equipment damage. Special attention should be placed on CSIs to prevent the potential catastrophic or critical consequences of failure. Significant problems occurred when DoD purchased CSIs from suppliers with limited knowledge of the item's design intent, application, failure modes, failure effects, or failure implications. The definition of CSI is not to be confused with the MIL-STD-882E definition of a Safety Critical Item (SCI). A SCI is "a hardware or software item that has been determined through analysis to potentially contribute to a hazard with catastrophic or critical mishap potential, or that may be implemented to mitigate a hazard with catastrophic or critical mishap potential."

The purpose of CSI analysis is to ensure that Program Managers for DoD acquisition programs who enter into contracts involving CSIs do so only with resources approved by the Design Control Activity (DCA). The DCA is defined by law as the systems command of a military department. The DCA is responsible for the airworthiness or seaworthiness certification of the system in which a CSI is used.

The intent of CSI laws, policies, regulations, and guidance is to avoid hazards through mitigating receipt of defective, suspect, improperly documented, unapproved, and fraudulent parts having catastrophic potential. These statutory requirements are contained in section 802 of Public Law 108-136, enacted to address aviation CSIs, and section 130 of Public Law 109-364, enacted to address ship CSIs, embedded in section 2319 of title 10, United States Code. The statute addresses three specific areas:

- Establish that the DCA is responsible for processes concerning the management and identification of CSIs used in procurement, modification, repair, and overhaul of aviation and ship systems.
- Require that DoD work only with sources approved by the DCA for contracts involving CSIs.
- Require that CSI deliveries and services performed meet all technical and quality requirements established by the DCA.

CSI policies and guidance ensure that items of supply that are most critical to operational safety are rigorously managed and controlled in terms of:

- Supplier capability
- Conformance to technical requirements
- Controls on changes or deviations
- Inspection, installation, maintenance, and repair requirements

DoD 4140.1-R, DoD Supply Chain Materiel Management Regulation establishes top-level procedures for the management of aviation CSIs. The Joint Aeronautical Commanders Group issued the Aviation Critical Safety Items (CSIs) Management Handbook. This guidance establishes standard user-level operating practices for aviation CSIs across the Services, the Defense Logistics Agency (DLA), the Defense Contract Management Agency (DCMA), and other Federal agencies. Appendix I of the Aviation CSI Management Handbook is a joint Military Service/Defense Agency instruction on "Management of Aviation Critical Safety Items" issued on January 25, 2006. This instruction (SECNAVINST 4140.2, AFI 20-106, DA Pam 95-9, DLAI 3200.4, and DCMA INST CSI (AV)) addresses requirements for identifying, acquiring, ensuring quality, managing, and disposing of aviation CSIs. Similar policies and guidance are being developed and/or revised to address ship CSIs as defined by public law.

The Defense Federal Acquisition Regulation Supplement (DFARS) was amended to implement the contractual aspects regarding aviation CSIs. Comparable DFARS amendments are being developed to address ship CSIs. DFARS 209.270 states that the DCA is responsible to:

- Identify items that meet aviation CSI criteria
- Approve qualification requirements
- Qualify suppliers

This supplement states that the contracting activity contracts for aviation CSIs only with suppliers approved by the DCA. Program Managers should coordinate with the contracting activity to ensure that they contract for aviation CSIs only with suppliers approved by the DCA

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and that nonconforming aviation CSIs are to be accepted only with the DCA's approval, as required by DFARS 246.407. DFARS 246.407 was amended to state that DCA authority can be delegated for minor nonconformance. DFARS 246.504 requires DCA concurrence before certificates of conformance are issued to accept aviation CSIs.

Because the system developer may uncover problems with products after items are delivered, DFARS 246.371 and 252.246-7003 require the developer to notify the procuring and contracting officers within 72 hours after discovering or obtaining credible information that a delivered CSI may have discrepancies that affect safety. Program Managers should coordinate with the contracting authority to be kept aware of materiel recalls and shortfalls that may impact production rates and sustainment.

The CSI list evolves as the design, production processes, and supportability analyses mature. Program Managers identify and document CSIs during design and development to influence critical down-stream processes such as initial provisioning, supply support, and manufacturing planning to ensure adequate management of CSIs throughout a system's Operations and Support (O&S) phase. The Program Manager should make provisions for developers including original equipment manufacturer (OEM) contractors to deliver an initial allocated baseline at the Preliminary Design Review (PDR), to include an initial list of proposed CSIs and a proposed process for selecting and approving CSIs as well as addressing the critical characteristics of those items. Prior to the Critical Design Review (CDR), the program office, with support from the DCA and developer/OEM contractors, should ensure there is a clear understanding of CSI processes, terms, and criteria. The initial product baseline is delivered at CDR and at that time the program should have 100% of drawings completed for the CSIs. Throughout Low-Rate Initial Production (LRIP) (if applicable), conduct of the Physical Configuration Audit (PCA), and establishment of the final product baseline, the program should update the CSI list and review it to ensure the list reflects the delivered system. Before the Full-Rate Production / Full Deployment Decision Review (FRP/FD DR), a final CSI list should be documented and approved by the DCA.

4.3.18.7. Demilitarization and Disposal

4.3.18.7. Demilitarization and Disposal

The incorporation of demilitarization (DEMIL) and disposal requirements into the initial system design is critical to ensure compliance with:

- All DoD DEMIL and disposal policies.
- All legal and regulatory requirements and policies relating to safety (including explosive safety), security, and the environment.

Program Managers and Program Support Managers should ensure, as an essential part of systems engineering, that DEMIL and disposal requirements are incorporated in system design to minimize DoD's liabilities, reduce costs, and protect critical program information and technology. This includes integrating DEMIL and disposal into the allocated baseline approved at the Preliminary Design Review (PDR) and refining DEMIL and disposal requirements in the

initial product baseline at the Critical Design Review (CDR). DEMIL and disposal requirements are included in the program's Systems Engineering Plan (SEP), the Life-Cycle Sustainment Plan (LCSP), and the contract(s). For munitions programs, DEMIL and disposal documentation need to be in place before the start of Developmental Test and Evaluation.

DEMIL renders safe and eliminates functional capabilities and inherent military design features from both serviceable and unserviceable DoD materiel. It is the act of destroying the military offensive or defensive advantages inherent in certain types of equipment or material. DEMIL may include mutilation, scrapping, melting, burning or alteration designed to prevent the further use of this equipment and material for its originally intended military or lethal purpose. Systems Engineers integrate DEMIL considerations into system design to recover critical materials and protect assets, information, and technologies, from uncontrolled or unwanted release and disruption or reverse engineering. Program Managers should ensure the DEMIL of materiel is accomplished in accordance with DoDI 4160.28, DoD Demilitarization (DEMIL) Program.

Disposal is the process of reusing, transferring, donating, selling, destroying, or other ultimate disposal of excess surplus and foreign excess property. Disposal first ensures adequate screening is accomplished to satisfy that all valid DoD and other United States Government agency needs are met. After assurances that Government needs for surplus DoD property are met, the materiel disposition process:

- Permits authorized transfer or donation to Government or non-Government entities
- Obligates DoD to obtain the best available monetary return to the Government for property sold

Program Managers ensure disposal is accomplished in accordance with DoD 4140.1-R, Supply Chain Materiel Management Regulation and DoD 4160.21-M, Defense Materiel Disposition Manual.

The program's plan for demilitarization and disposal of DoD excess and surplus property protects the environment and personnel and minimizes the need for abandonment or destruction. During systems design, the Systems Engineer supports the Program Manager's plans for the system's demilitarization and disposal, through the identification and documentation of hazards and hazardous materials related to the system, using MIL-STD-882E, DoD Standard Practice for System Safety. Early, balanced analyses of ESOH hazards relative to the system's design, enable the Program Manager to make informed decisions based on alternatives and provide a clear understanding of trade-offs and consequences, both near term and over the systems life cycle.

4.3.18.8. Diminishing Manufacturing Sources and Material Shortages

4.3.18.8. Diminishing Manufacturing Sources and Material Shortages

Diminishing Manufacturing Sources and Material Shortages (DMSMS) is the loss, or impending loss, of manufacturers or suppliers of items, raw materials, or software. DMSMS-generated shortages in the ongoing production capability or life-cycle support of a weapon system or shortages in any training, support, or test equipment already in the field can endanger mission

effectiveness. While DMSMS issues can be caused by many factors, their occurrence is inevitable.

The Program Manager should incorporate a technology management strategy into design activities as a best practice to reduce DMSMS cost and readiness impacts throughout the life cycle. The Program Manager and Systems Engineer should develop a technology management strategy for maintaining insight into technology trends, and internal product changes by the manufacturer and testing the effects of those changes on the system when necessary. This insight into technology trends could potentially:

- Result in seamless upgrade paths for technologies and system elements
- Provide a timetable for replacing system elements even if they are not obsolete

The Systems Engineer should be aware of and consider DMSMS management during system design. Following are several practices that the program should consider to minimize DMSMS risk throughout the life cycle of the system:

- Avoid selecting technology and components that are near the end of their functional life
- During the design process, proactively assess the risk of parts obsolescence while selecting parts
- When feasible, use an Open Systems Architecture (OSA) to enable technology insertion/refreshment more easily than with design-specific approaches
- Proactively monitor supplier bases to prevent designing in obsolescence; participate in cooperative reporting forums, such as the Government-Industry Data Exchange Program (GIDEP), to reduce or eliminate expenditures of resources by sharing technical information essential during research, design, development, production and operational phases of the life cycle of systems, facilities and equipment
- Proactively monitor potential availability problems to resolve them before they cause an impact in performance readiness or spending

A useful resource for additional guidance is SD-22, "Diminishing Manufacturing Sources and Material Shortages (DMSMS) Guidebook."

4.3.18.9. Environment, Safety, and Occupational Health

4.3.18.9. Environment, Safety, and Occupational Health

Environment, Safety, and Occupational Health (ESOH) analyses are an integral, ongoing part of the systems engineering (SE) process throughout the life cycle. The benefits of early integration of ESOH considerations include:

- Mitigation of program cost and schedule risks from actions that cause damage to people, equipment, or the environment
- Reduction of Operations and Support and disposal costs
- Provision of a safe, suitable, supportable, and sustainable capability able to operate world-wide

Throughout each acquisition phase, programs conduct the ESOH analyses to:

- Identify and mitigate potential risks to the system and its associated personnel
- Manage ESOH design considerations from the beginning of the SE effort
- Plan for compliance with the National Environmental Policy Act (NEPA) and Executive Order (EO) 12114, Environmental Effects Abroad of Major Federal Actions
- Ensure compliance with statutory ESOH requirements

Efforts to identify and analyze hazards, and mitigate ESOH risks provide information needed for informed design decisions and development of ESOH-related documentation for milestone decisions.

DoD defines ESOH in MIL-STD-882E, DoD Standard Practice for System Safety as *"the combination of disciplines that encompass the processes and approaches for addressing laws, regulations, EOs, DoD policies, environmental compliance, and hazards associated with environmental impacts, system safety (e.g., platforms, systems, system-of-systems, weapons, explosives, software, ordnance, combat systems), occupational safety and health, hazardous materials management, and pollution prevention."*

ESOH System Design Requirements

The Systems Engineer identifies the ESOH requirements applicable to the system throughout its life cycle from statutes, regulations, policies, design standards, and capability documents. From these requirements, the Systems Engineer should derive ESOH design requirements and include them in capability documents, technical specifications, solicitations, and contracts.

ESOH in Program Documents

The Acquisition Program Office ESOH-specific documents are the Programmatic ESOH Evaluation (PESHE) and the NEPA/EO 12114 Compliance Schedule. The Systems Engineering Plan (SEP) contains the ESOH management planning information. The SEP, PESHE, and NEPA/EO 12114 Compliance Schedule provide inputs to program documentation that include, but are not limited to: Technology Development Strategy (TDS), Test and Evaluation Strategy (TES), Test and Evaluation Master Plan (TEMP), Life-Cycle Sustainment Plan (LCSP), Corrosion Prevention and Control Plan (CPCP), system specifications, solicitations, and contracts; and capability documents.

The SEP contains ESOH design considerations as an integral part of the requirements analysis process, including trade study criteria. ESOH design considerations are particularly important for Milestone A to ensure SE addresses ESOH during the Technology Development (TD) phase, which includes a significant amount of the design development, testing, and the Preliminary Design Review. SEP Table 4.6-1 includes the information listed in Table 4.3.18.9.T1. Additional ESOH details are provided in SEP Sections 3.4 and 3.6; Tables 2.2-1, 3.4.4-1, 3.4.4-2, and 4.4-1; and Figure 3.4.1-1.

Table 4.3.18.9.T1. ESOH Information in SEP

Column Heading in SEP Table 4.6-1	Expected Information (provided or attached)
Cognizant PMO Organization	Organizational structure for integrating ESOH (or refer to Table 3.4.4-2 if it includes the ESOH team details) and the Program Office ESOH point of contact
Certification	Required ESOH approvals, endorsements, releases, and the designated high and serious risk acceptance user representative(s)
Documentation	PESHE and NEPA/EO 12114 Compliance Schedule
Contractual Requirements (CDRL#)	ESOH contractual language, ESOH Contract Data Requirements List (CDRL) items, and ESOH DFARS clauses
Description / Comments	Description of how design minimizes ESOH risks by summarizing how the program has integrated ESOH considerations into SE processes including the method for tracking hazards and ESOH risks and mitigation plans throughout the life cycle of system

The PESHE documents the ESOH design consideration data produced by executing the ESOH planning described in the SEP. The PESHE includes, but is not limited to:

- ESOH Risk Matrices (for hardware and software) used by the program with definitions for severity categories, probability levels, risk levels, and risk acceptance and user representative concurrence authorities.
- The following data for each hazard: Hazard Tracking System (HTS) identification number, hazard description, potential mishap, initial Risk Assessment Code (RAC) and risk level, mitigation measure(s) and funding status, target RAC and risk level, current RAC and risk level, and risk acceptance and user concurrence status (**NOTE:** providing an electronic copy of the current data from the HTS would satisfy this requirement).
- The following data for each hazardous material, hazardous waste, and pollutant associated with the system: the specific uses, locations, quantities, and plans for their minimization and/or safe disposal (**NOTE:** providing an electronic copy of the current data from either the HTS (if it includes this information) or the hazardous materials management data would satisfy this requirement).
- Environmental impact information not included in the HTS or hazardous materials tracking system needed to support installation and range analyses.

NOTE: The results of the sustainability analysis (see DAG section 4.3.19.2. Sustainability Analysis) should be used to inform the hazard analysis.

DoDI 5000.02, Enclosure 12 requires that each program maintain a NEPA/EO 12114 compliance schedule. This schedule includes, but is not limited to:

- Each proposed action (e.g., testing or fielding)
- Proponent (as defined in DoDI 4715.9) for each action
- Anticipated start date for each action at each specific location
- Anticipated NEPA/EO 12114 document type

- Anticipated start and completion dates for each document
- The document approval authority

Because actions occurring during the TD phase may require NEPA/EO 12114 compliance, the program should develop a TD Compliance Schedule for inclusion in the SEP. DoDI 5000.02, Enclosure12 also requires programs to support other organizations NEPA/EO 12114 analyses involving their systems.

ESOH Activities by Phase

Table 4.3.18.9.T2. aligns typical ESOH activities by phase.

Table 4.3.18.9.T2. ESOH Activities by Phase

Acquisition Phase	Typical ESOH Activities
Materiel Solution Analysis (MSA)	• Participate in Analysis of Alternatives (AoA) • Provide inputs to the SEP, draft Capability Development Document (CDD), Corrosion Prevention and Control (CPC) Planning, TDS, Test and Evaluation (T&E) Strategy (TES), Life-cycle Sustainment Plan (LCSP), and draft Request for Proposal (RFP)
Technology Development (TD)	• Participate in prototyping and design development through the IPT structure • Prepare initial PESHE and NEPA/EO 12114 Compliance Schedule • Ensure NEPA/EO 12114 compliance, ESOH risk acceptance, Preliminary Design Review (PDR) risk reporting, and safety releases • Inputs to SEP, CPC Planning, final CDD, Test and Evaluation Master Plan (TEMP), LCSP, and draft RFP
Engineering and Manufacturing Development (EMD)	• Participate in trades and design development activities through the IPT structure • Evaluate T&E results, to include assessment of ESOH risk mitigations • Update NEPA/EO 12114 Compliance Schedule and PESHE; support NEPA/EO 12114 compliance activities, ESOH risk acceptance • Obtain required ESOH approvals, endorsements, and releases; provide inputs to the SEP, CPC Planning, LCSP, Capability Production Document (CPD), and draft RFP
Production and Deployment (P&D)	• Participate in initial Configuration Control Board (CCB) process • Evaluate T&E results, to include assessment of ESOH risk mitigations • Analyze deficiency reports • Review Physical Configuration Audit (PCA) • Update NEPA/EO 12114 Compliance Schedule and PESHE • Support NEPA/EO 12114 compliance activities and ESOH risk mitigations • Obtain required ESOH approvals, endorsements, and releases • Support Initial Operational Capability (IOC) and Full Operational Capability (FOC) • Provide inputs to the LCSP, CPC Planning, and product support package

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Acquisition Phase	Typical ESOH Activities
Operations and Support (O&S)	• Participate in mishap investigations and the CCB process • Analyze deficiency reports • Keep the PESHE data current; support NEPA/EO 12114 compliance activities and ESOH risk acceptance • Provide inputs to draft Joint Capabilities Integration and Development System (JCIDS) documents and CPC Planning

ESOH Risk Management

The Systems Engineer uses the MIL-STD-882E process to identify and assess hazards (to include software safety), eliminate hazards where possible, and manage ESOH risks where hazards cannot be eliminated. MIL-STD-882E provides a matrix and defines probability and severity criteria to categorize ESOH risks. Prior to exposing people, equipment, or the environment to known system-related hazards, the Systems Engineer ensures ESOH risks are formally accepted, which includes formal concurrence on high and serious risks by the designated user representative as defined in MIL-STD-882E (or by each participating Service user representative in a Joint program). DoDI 5000.02 identifies the appropriate management level authorized to accept ESOH risks.

For Joint programs, the Component Acquisition Executive of the Lead Executive Component should be the acceptance authority for high-level risks. The program documents formal risk acceptances as part of the program record (e.g., Hazard Tracking System (HTS)). If a risk level increases for a hazard, a new risk acceptance is required prior to exposing people, equipment, or the environment to the increased risk. The program also participates in system-related mishap investigations to assess contributing hazards, risks, and mitigations.

DoDI 5000.02, Enclosure 12 requires programs to report the status of current high and serious ESOH risks at program reviews and fielding decisions and the status of all ESOH risks at technical reviews. The purpose of this reporting is to inform the Milestone Decision Authority (MDA), Program Executive Office (PEO), Program Manager, and end user about trades being made and ESOH risks that need to be accepted. Each ESOH risk report includes the following: the hazard, potential mishap, initial Risk Assessment Code (RAC) and risk level, mitigation measure(s) and funding status, target RAC and risk level, current RAC and risk level, and risk acceptance / user representative concurrence status.

Hazardous Materials (HAZMAT) Management

When Hazardous Materials (HAZMAT) and chemicals/materials of evolving regulatory concern are designed into the system or used for system operation and maintenance, the Systems Engineer assesses and documents the ESOH risks for each combination of HAZMAT and application. The Systems Engineer also documents:

- The locations, quantities, and usage of each HAZMAT

- Safe demilitarization and disposal requirements
- Energetic qualification information, as applicable
- Reasonably anticipated quantities of hazardous waste generated during normal operation and maintenance
- Hazardous emissions/discharges including those anticipated in emergency situations
- Special training, handling, and storage requirements

The Systems Engineer manages hexavalent chromium usage in systems to balance the requirements for corrosion control and prevention and the procedures in DFARS Subpart 223.73 - Minimizing the Use of Hexavalent Chromium. For more information on chemicals/materials of evolving regulatory concern, refer to the DENIX website.

Safety Release for Testing

The Program Manager, in concert with the user and the T&E community, provides safety releases (to include formal ESOH risk acceptance in accordance with DoDI 5000.02, Enclosure 12, Section 6), to the developmental and operational testers before any test using personnel. The safety release addresses each system hazard present during the test and include formal risk acceptance for each hazard. The program's safety release is in addition to any test range safety release requirements, but it should support test range analyses required for a range-generated test release. The program documents safety releases as part of the Program Record.

The Program Manager should provide a transmittal letter to the involved test organization with a detailed listing of the system hazards germane to the test that includes the current risk level and documented risk acceptance along with information on all implemented mitigations.

Green Procurement Program (GPP)

In an effort to enhance and sustain mission readiness over the system life cycle, reduce reliance on resources, as well as reduce the DoD footprint, programs should follow the policy and procedures identified in the DoD Green Procurement Program (GPP). GPP benefits include:

- Reducing resource consumption
- Ensuring availability of chemicals and materials
- Reducing waste generation
- Contributing to regulatory compliance

Program Managers should implement the applicable GPP procedures in Federal Acquisition Regulation (FAR) Subparts 23.2, 23.4, 23.7 and 23.8 to select materials and products that are energy-efficient, water conserving, and environmentally preferable. More information on GPP is available on the DENIX website.

Key Resources

- Acquisition Community Connection/ESOH
- Defense Acquisition University Continuous Learning Modules "CLE 009 -- ESOH in

Systems Engineering" and "CLR 030 - ESOH in JCIDS"
- Defense Federal Acquisition Regulation Supplement (DFARS)
- Federal Acquisition Regulation (FAR)
- Joint Software System Safety Engineering Handbook, August 27, 2010
- MIL-STD-882E with 25 optional Tasks

4.3.18.10. Human Systems Integration

4.3.18.10. Human Systems Integration

Systems engineering (SE) addresses the three major elements of each system: hardware, software, and human. SE integrates human capability considerations with the other specialty engineering disciplines to achieve total system performance requirements by factoring into the system design the limitations of the human users.

During system design, Systems Engineer should apply Human Systems Integration (HSI) and Human Factors Engineering (HFE) design criteria, principles, and practices described in MIL-STD-1472, Human Engineering and MIL-STD-46855A, Human Engineering Requirements for Military Systems, Equipment and Facilities.

The HSI effort minimizes ownership costs and ensures the system is built to accommodate the human performance characteristics of users who operate, maintain, and support the total system. The total system includes not only the mission equipment but also the users, the training and training devices, and the operational and support infrastructure.

The Program Manager has overall responsibility for integrating the HSI effort into the system program. These responsibilities are described in DAG Chapter 6 Human Systems Integration.

The Systems Engineer supports the Program Manager and is responsible for HSI. The Systems Engineer should work with the manpower, personnel, training, safety, health, habitability, personnel survivability, and HFE stakeholders to develop the HSI effort. The Systems Engineer translates and integrates those human capability considerations, as contained in the capabilities documents, into quantifiable system requirements. Requirements for conducting HSI efforts should be specified for inclusion in the Statement of Work and contract and included in the Systems Engineering Plan (SEP), specifications, the Test and Evaluation Master Plan (TEMP), the Life-Cycle Sustainment Plan (LCSP), and other appropriate program documentation. The SEP Outline requires that HSI be addressed as a mandatory design consideration in Table 4.6-1.

Elements of an effective HFE effort, described in DAG Chapter 6 Human Systems Integration, should:

- Provide a better operational solution to the warfighters
- Lead to the development or improvement of all human interfaces of the system
- Achieve required effectiveness of human performance during system testing, operation, maintenance, support, transport, demilitarization and disposal

- Make for more economical demands upon personnel resources, skills, training, and costs

4.3.18.11. Insensitive Munitions

4.3.18.11. Insensitive Munitions

Insensitive Munitions minimize the probability of inadvertent initiation and the severity of subsequent collateral damage to weapon platforms, logistic systems, and personnel when munitions are subjected to unanticipated stimuli during manufacture, handling, storage, transport, deployment, or disposal, or due to accidents or action by an adversary.

Insensitive Munitions is a component of explosive ordnance safety described in section 2389 of title 10, United States Code, which specifies that it is the responsibility of DoD to ensure insensitive munitions under development or procurement are safe, to the extent practicable, throughout development and fielding when subjected to unplanned stimuli, e.g., electro-magnetic interference, vibration, or shock. The Program Manager and the Systems Engineer for munitions programs such as: ordnance, warheads, bombs, and rocket motors and munitions handling, storage, and transport programs have an overriding responsibility to address safety aspects of their programs in trade studies, design reviews, milestone reviews, and in JCIDS documents.

The Program Manager and Systems Engineer for munitions acquisition programs, regardless of the ACAT level, should have safety as a top consideration when performing trade studies or making program decisions. The term "Insensitive Munitions" implies that unanticipated stimuli will not produce an explosive yield, in accordance with MIL-STD-2105D, Hazard Assessment Tests for Non-Nuclear Munitions. The Program Manager and cognizant technical staff should coordinate harmonized Insensitive Munitions/Hazard Classification (HC) test plans with the Service Insensitive Munitions/Hazard Classification (HC) review organizations. The Service organizations should coordinate the Insensitive Munitions/Hazard Classification (HC) with the Joint Services Insensitive Munitions Panel (JSIMTP), Joint Service Hazard classifiers, and the DoD Explosives Safety Board (DDESB), is chartered by DoDD 6055.9E, Explosives Safety Management and the DDESB. Aspects of Insensitive Munitions also apply to nuclear weapons but are not addressed herein.

The primary document to address Insensitive Munitions is the Insensitive Munitions Strategic Plan (IMSP), as required by USD(AT&L) memorandum, "Insensitive Munitions Strategic Plans," July 21, 2004, which establishes Department of Defense Policy for the annual submission of Insensitive Munitions Strategic Plans to the Joint Requirements Oversight Council (JROC) and Office of the Under Secretary of Defense (Acquisition, Technology, and Logistics) (OUSD(AT&L)), by the Program Executive Officer (PEO) for munitions programs. USD(AT&L) memorandum, "Joint Insensitive Munitions Test Standards and Compliance Assessment." February 10, 2010, provides for oversight and compliance assessment. The DoD Standard Operating Procedure (SOP) for IMSP and the Plan of Action and Milestones (POA&M), defined by Joint Business Rules, March 2011, define the content of the IMSP, which spans the Future Years Defense Plan (FYDP) and includes currently funded as well as unfunded requirements. The DoD Acquisition Manager’s Handbook for Insensitive Munitions contains the

above-referenced documents and appendices for each Service's policy and review board process.

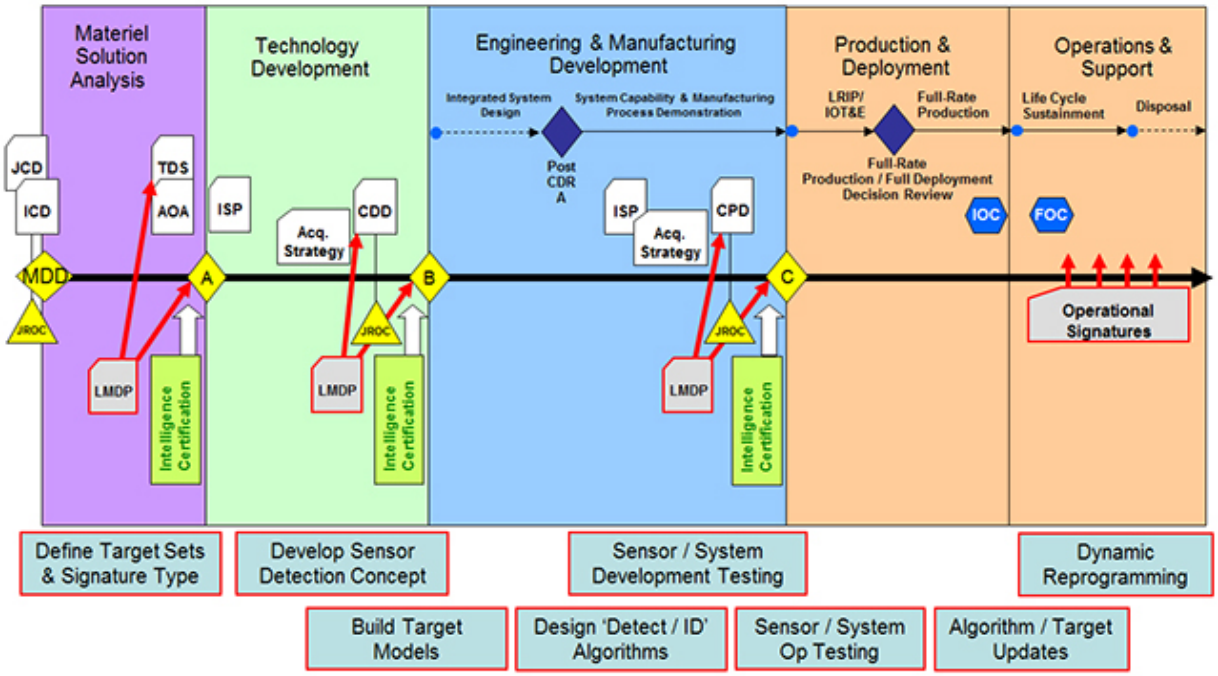
The IMSP is the primary program output required by USD(AT&L) and the Joint Staff to provide evidence that the program is in compliance with all applicable laws and regulations. Both the Component-level and DoD-level insensitive munitions review organizations can provide additional guidance and can assess the adequacy of the IMSP. In addition to the IMSP, the Analysis of Alternatives (AOA), Acquisition Strategy (AS), Systems Engineering Plan (SEP), Test and Evaluation Master Plan (TEMP), Risk Management Plan, Corrosion Prevention and Control Plan (CPCP), and other JCIDS documents called for in CJCSI 3170 and the JCIDS Manual (requires Common Access Card (CAC) to access website), address aspects of explosive ordnance safety, including Insensitive Munitions.

4.3.18.12. Intelligence (Life-Cycle Mission Data Plan)

4.3.18.12. Intelligence (Life-Cycle Mission Data Plan)

Modern weapon systems are inherently dependent on a variety of scientific and technical intelligence products throughout every stage of their life cycle. Intelligence Mission Data (IMD) provides essential data for building system models, developing algorithms, optimizing sensor design, system testing and evaluation, and validating sensor functionality. Therefore, it is imperative to ensure IMD is considered, identified, and applied throughout the life cycle of IMD-dependent programs by informing the Analysis of Alternatives (AoA) and continuing through disposal. See Figure 4.3.18.12.F1.

Figure 4.3.18.12.F1. Intelligence Mission Data (IMD) Life Cycle Timeline



The Program Manager, Systems Engineer, and Test and Evaluation Manager are the primary functional program office leads responsible for the identification and programming of unique IMD to support the program beginning at MS A (see DoDD 5250.01).

IMD is necessary to:

- Derive functional baseline requirements and intelligence signature requirements (sensors, algorithms, and other entities that require intelligence data) identified in the Life-Cycle Mission Data Plan (LMDP) (based upon mission and environment) (see LMDP template)
- Allocate the functional baseline necessary to identify sensors, algorithm, and intelligence database
- Design, develop, test, and evaluate IMD dependent sensors, systems, processes, and interfaces
- Conduct trade-off studies, effectiveness analysis, and risk assessments
- Develop technical performance measures to inform test and evaluation
- Inform decision-making and science and technology investments for identifying the intelligence signature, and intelligence mission data, production, and collection requirements
- Assess system capability and limitations
- Ensure system flexibility and agility in response to dynamic threat and environment

DAG Chapter 8 Intelligence Analysis Support to Acquisition provides key linkages to the System Requirements Document (SRD), Systems Engineering Plan (SEP), and Test and Evaluation Master Plan (TEMP).

These three products are directly affected by the intelligence signature and mission data requirements.

4.3.18.13. Interoperability and Dependencies

4.3.18.13. Interoperability and Dependencies

Almost all DoD systems operate in a system-of-systems (SoS) context relying upon other systems to provide desired user capabilities, making it vital that interoperability needs and external dependencies are identified early and incorporated into system requirements. When identifying system requirements, it is critical to consider the operational and SoS context (see DAG section 4.2.1.2. Systems of Systems). These include, but are not limited to, physical requirements (e.g., size, power limits, etc.), electronic requirements (e.g., signature, interference, etc.) and information exchange/management (e.g., network, bandwidth, information needs, etc.). These also include interdependencies with other systems. For efficiency, systems often rely on either services provided by other systems during operations or reuse of system elements developed by other programs.

The Program Manager is responsible for ensuring that the operational and SoS context for the system are well understood.

The Systems Engineer has the primary responsibility for ensuring all interoperability and dependency impacts are analyzed and collaborated with the appropriate internal/external stakeholders and are translated into system requirements and design considerations.

Analysis conducted for the SoS contexts for the system -- where the system is dependent on other systems and where the system needs to interact with other systems - enables translation of I&D into system requirements. I&D requirements call for collaborative implementation approaches with external organizations, including identification, management, and control of key interfaces. Areas of dependency and interoperability should be reviewed for risks to the program and plans made to manage and mitigate those risks. This review includes system interdependencies (e.g., weapon may depend on new sensor capabilities provided by another system) and information exchanges with other systems required to support mission capabilities. For efficiency, systems may rely on system elements developed by others for key functionality, either through services (e.g., weather information) provided by other systems or through reuse of system elements (e.g., engines, radios) developed by other programs. These contexts are analyzed to identify system requirements and risks, including actions needed by external parties (e.g., other systems or infrastructure) for the system to meet user requirements.

Additional DoD policy and guidance regarding I&D, summarized below, are directed at ensuring that systems work effectively with other systems:

- Interoperability of information technology and National Security System (NSS) acquisition programs are required to comply with DoDD 4630.05, DoDI 4630.8, CJCSI 3170.01, the JCIDS Manual (requires Common Access Card (CAC) to access website), CJCSI 6212.01, Public Law 104-106, and section 3506 of title 44, United States Code.
- DoDD 5000.01, Enclosure 1 :
    - Ability of acquired systems to exchange information and services with other systems and to interoperate with other United States forces and coalition partners, and as appropriate with other United States Government departments and agencies
    - Providing systems and systems of systems that are interoperable and able to communicate across a universal infrastructure that includes organizational interactions, other systems, networks, and information exchange capabilities
- DoDI 5000.02, Enclosure 2 : An integrated system design that defines system and system-of-systems functionality and interfaces, and reduces system-level risk
- DoDI 2010.06 : Pursuing opportunities throughout the acquisition life cycle that enhance international cooperation and improve interoperability

4.3.18.14. Item Unique Identification

4.3.18.14. Item Unique Identification

Properly implemented, Item Unique Identification (IUID)-enabled Serialized Item Management (SIM) provides a capability that allows DoD to locate, control, value, and manage its assets throughout the life cycle. A robust SIM program provides tools and processes to assist informed decision making to achieve both better weapon system reliability and readiness at reduced total

ownership cost. As a key enabler, IUID is a systematic process to globally and unambiguously distinguish one item from all other items that DoD buys or owns. IUID-enabled SIM provides DoD with a standard methodology to:

- Consistently capture the value of all individual items it buys/owns
- Trace these items during their use
- Combat counterfeiting of parts
- Associate valuable business intelligence to an item throughout its life cycle via automatic identification technology and connections to automated information systems

Program Managers and Product Support Managers should budget, plan for, and implement IUID-enabled SIM as an integral activity within MIL-STD-130 requisite item identification processes to identify and track applicable major end items and configuration-controlled items. IUID implemented in accordance with DoDI 8320.04 and IUID Implementation Plans are required for all milestone decisions as directed by DoDI 5000.02. IUID-specific design considerations are required in the Systems Engineering Plans (SEP), and SIM planning and implementation required by DoDI 4151.19 are addressed in the Life-Cycle Sustainment Plan (LCSP).

The Systems Engineer considers what to mark and how to incorporate the IUID mark within MIL-STD-130 item marking requirements when formulating design decisions. In addition, the Systems Engineer considers where product and maintenance information reside and how the life-cycle data is used within the configuration management and product support systems - including new and legacy information systems.

The DoD Guide to Uniquely Identifying Items, provides guidance on implementing IUID intended for use by Department of Defense (DoD) contractors and their suppliers who put unique item identifier (UII) marks on new items during production, as directed in the contract.

4.3.18.15. Open Systems Architecture

4.3.18.15. Open Systems Architecture

Open Systems Architecture (OSA) benefits Program Managers by using established and working frameworks that are already crafted with component reuse in mind, such that many common services and applications can be quickly instantiated with small effort from program to program. Adding features to address evolving threats to an already tested, fielded, and working component is far less risky than a "ground up" new development start. OSA is identified as a key tenet of Better Buying Power, under Promoting Effective Competition, because it enhances system interoperability and the ability to integrate new capabilities without redesign of entire systems or large portions of the enterprise. It is also addressed in DoDI 5000.02.

An open architecture is defined as a technical architecture that adopts open standards supporting a modular, loosely coupled, and highly cohesive system structure that includes the publishing of key interfaces within the system and relevant design disclosure. The key enabler for open architecture is the adoption of an open business model that requires doing business in a transparent way that leverages the collaborative innovation of numerous participants across the

enterprise, permitting shared risk, maximized reuse of assets, and reduced total ownership costs. The combination of open architecture and an open business model permits the acquisition of OSA that yield modular, interoperable systems allowing components to be added, modified, replaced, removed, and/or supported by different vendors throughout the life cycle in order to afford opportunities for enhanced competition and innovation.

OSA benefits warfighters by:

- Reducing operator learning curves by using systems that have similar functions and are operated in similar ways thereby reducing costs
- Increasing interchangeability
- Reducing support and sustainment costs

The engineering trade analyses conducted prior to MS B help determine which system elements of program architecture can be adapted to OSA in order to reduce program cost and development time lines. Correct application of OSA principles and practices results in modular architecture components having well-defined functions and open standards-based interfaces. Threat analyses, functional criticality analyses, technology opportunities, and evolved capability assessments are examples of assessments against the functional architecture to determine what components should be OSA-enabled. When these architecture components require upgrade, replacement is competitive, faster, and cheaper because the OSA-enabled components are modular. Because system functional architecture maps from the higher-level enterprise architecture, engineering trade analyses and assessments supporting OSA should be completed and OSA-enabled architecture components specified, before contracts are let for technology development of those architecture components. Successful implementation of OSA approaches requires the synchronized acquisition of data rights for OS and interfacing architecture elements. These data rights are initially structured to support acquisition of modular open system designs but also should address life-cycle support.

Acquisition programs adopting OSA benefit from:

- Reduced acquisition and sustainment cost without sacrificing capability
- Reduced reliance on single-source vendors ("Vendor Lock")
- Shortened program acquisition time line
- Enhanced rapid and agile development
- Accelerated transition from science and technology into acquisition due to modular insertion
- Increased ability to retrofit/upgrade system elements for new/evolving capability
- Enhanced incremental approach to capabilities
- Increased competition and innovation
- Enhanced ability to create security structures within a design to reduce security risk

DoDI 5000.02 identifies the use of OSA as a key systems engineering (SE) approach in Enclosure 12, paragraph 8. The USD(AT&L) memorandum, "Better Buying Power 2.0: Continuing the Pursuit for Greater Efficiency and Productivity in Defense Spending," November 13, 2012, raises the relevance of OSA along with acquisition of data rights for appropriate

architecture elements. The overarching business case for DoD is increasing the level of competition by enabling small business. Programs should develop a business model documenting the strategy for use of OSA and associated data rights. The OSA-DR Charter signed by USD(AT&L) on February 15, 2012, requires programs to issue business case guidance to aid programs in developing their business models.

The DoD Open Systems Architecture Contract Guidebook for Program Managers contains guidance regarding contract language programs should use to acquire data rights in support of a program's OSA strategy. Additional information and supporting details amplifying each aspect of OSA is available on the DASD(SE) website.

The Program Manager should:

- Establish supportive requirements; business practices; and technology development, acquisition, test and evaluation, and product support strategies for effective development of open systems
- Ensure their data deliverables support their Technical Data Rights Strategy (see Acquisition Strategy template) and secure the necessary data rights to support and sustain the system
- Map Open Systems strategy and functional architecture to SOW requirements, Data Item Descriptions (DIDs), and CDRLs consistently across the enterprise
- Ensure compliance
- Consider including OSA as one of the evaluation criteria for contract proposals
- Determine the appropriateness of an OSA approach by considering software constraints, security requirements and procedures, availability and cost of data rights, life-cycle affordability, and reliability of open standards, as well as other relevant factors such as environmental constraints (e.g., temperature, humidity, and environment, safety, and occupational health (ESOH))

The Systems Engineer should:

- Employ an overall plan for and OSA approach that supports program functional architecture and that uses prescribed USD(AT&L) business case analyses
- Ensure the program functional architecture is structured to accommodate OSA where feasible, due to the high potential for reduced risk and cost
- Assess performance
- Balance current implementation of OSA with performance and evolving technology at the physical level; OSA establishes a technical baseline that may support modular architecture, but formally constrains the interfaces between modules, where interfaces close to current performance limits may quickly become obsolete
- Technically evaluate the appropriateness of an OSA approach by considering software constraints, security requirements and procedures, availability and cost of data rights, life-cycle affordability, and reliability of open standards, as well as other relevant factors such as environmental constraints (e.g., temperature, humidity, and ESOH)

Modular open system designs, developed from the system architecture, should be analyzed at

each design review because there is a link between OSA and the level and type of technical data, computer software, and data rights the Government needs for life-cycle support. In many cases weapon systems using OSA system elements can have increased opportunities for competitive sourcing during the life-cycle sustainment, and a correspondingly less need for detailed design data and associated data rights. This benefit enables an incremental approach to capability adaptation in OSA-enabled systems and is a benefit of the modularity originally specified into the functional architecture.

Figure 4.3.18.15.F1. Sample OS and Data Rights Analysis

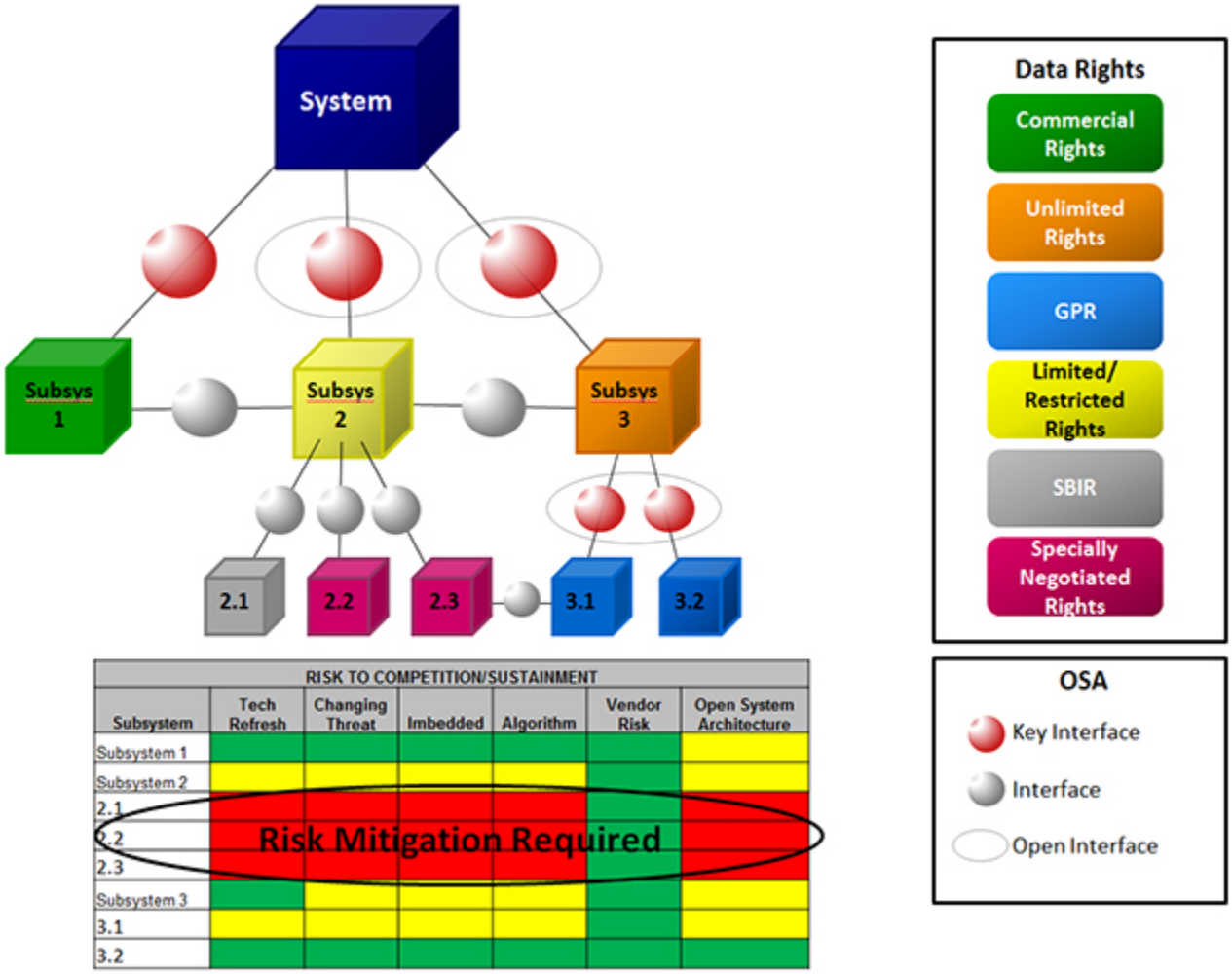


Figure 4.3.18.15.F1 depicts an example architectural approach for mapping and assessing which component interfaces can be open, how associated risk is ascertained, and visualizing the impact to interfaces with other system elements. The figure presents a top-level system view of the OSA characteristics of system architecture components. Not all interfaces need to be open at any one level of the design, only those that are required to meet anticipated incremental capability

updates or changes in threat or technology insertion. A system view such as this one includes a record of the data rights that are required to enable the planned OSA design. This is to initially ensure and, for the life-cycle sustainment, maintain the strong link between the OSA design and the acquired data rights that enable it. The levels of data rights that need to be required for each OSA-enabled architecture component are determined in order to assert the requisite contract requirements to obtain them. The data rights strategy ensures that enterprise-level data rights flow to system architecture components and that they support the system architecture. Levels of data rights are described in DAG Chapter 2 Program Strategies and in Appendix 9 of the OSA Contract Guidebook.

Successfully implementing an OSA strategy results in identification of required technical data and software deliverables that are necessary to field and maintain weapon systems and their logistics support. The Technology Development Strategy and Acquisition Strategy should be updated throughout the system's life cycle to reflect changes in the OSA approach resulting from technology and software evolutionary developments. The Systems Engineering Plan (SEP) also is updated to reflect the OSA-related updates and modifications employed throughout the system and its system elements.

Specific OSA-related data deliverables that should be required to include:

- Software Development Plans (DI-IPSC-81427A)
- Software Development Status Reports (DI-MCCR-80459)
- Software Development Summary Reports (DI-MCCR-80902)
- Software Design Descriptions (DI-IPSC-81435A)

In addition, the Program Manager should maintain an open systems management plan. The plan describes the offeror's approach to:

- OSA, modularity, and open design
- Inter-component dependencies
- Design information documentation
- Technology insertion
- Life-cycle sustainability
- Interface design and management
- Treatment of proprietary or vendor-unique elements
- Reuse of preexisting items including all commercial-off-the-shelf/non-developmental Item (COTS/NDI) components, their functionality and proposed function in the system
- Copies of license agreements related to the use of COTS/NDI components for Government approval

The open system management plan also should include a statement explaining why each COTS/NDI was selected for use.

Program products typically used in making decisions regarding OSA include:

- System Requirements

- Technology Development Strategy (TDS) or Acquisition Strategy (AS)
- Program Protection Plan (PPP)
- Analysis of Alternatives (AoA)
- Enterprise Architecture

OSA approaches and requirements should be addressed at design reviews, e.g., System Readiness Review (SRR), Preliminary Design Review (PDR), and Critical Design Review (CDR).

See DoD ASSIST homepage for more data item deliverables that may be appropriate for each specific program and DoD 5010.12-M for data deliverables.

4.3.18.16. Operational Energy

4.3.18.16. Operational Energy

Emerging threats to the logistic resupply of operational forces, the trend toward ever greater energy demand in the operational forces, and increasing costs to operate and resupply energy-intensive systems have all put increasing focus on lowering system and unit energy demand. Reducing the force's dependence on energy logistics can improve the force's mobility and resilience and increase its control over the timing and conditions of the fight. Focusing on energy as an explicit design consideration and systems engineering (SE) category is a significant change in practice and thinking, to help manage emerging operational challenges.

The Program Manager and Systems Engineer can help lower operational energy by addressing issues associated with the system's energy logistics support and power resupply frequency.

This approach should generate informed choices based on the threshold and objective values of the Energy Key Performance Parameter (KPP) for the system. For liquid energy-consuming systems, the top-level units of measure for the Energy KPP might be gallons of fuel demanded (consumed) over a defined set of duty cycles, or to accomplish a specified mission goal such as a sortie. These measures may be further decomposed into weight, range, electric power demand, and other relevant measures to inform the necessary SE trade analysis. The intended result is a comprehensive set of trade-space choices for industry to consider to deliver solutions that are not only energy efficient but also mission effective and affordable. See Joint Capabilities Integration and Development System (JCIDS) Manual (requires Common Access Card (CAC) to access website) and CJCSI 3170.01H linked at the end of this section.

Energy's relationship to performance arises from the operational context in which the system is used. Accordingly, the scenarios that illustrate how the system is used, as part of a unit of maneuver, are essential to understanding the energy supply and demand constraints to be managed. This is essentially the same approach as balancing survivability goals against lethality goals in the engineering trade space. Operational energy issues include:

- How the system and combat unit refuel/recharge in the battlespace scenarios, and how often

- How this refueling/recharging requirement might constrain our forces (limit their freedom of action, on-station time, signature, etc.)
- How the adversary depicted in the defining scenarios might delay, disrupt, and/or defeat our forces by interdicting this system's refueling/recharging logistics
- How much force protection could be diverted from combat missions to protecting these refueling/recharging events when and where required

Systems Engineers should consider incorporating energy demand in design, technology, materials, and related issues into the system trade space along with other performance issues, so that oppressive energy resupply needs are not inadvertently introduced in the attempt to achieve other performance goals (e.g., survivability, lethality). In practice, this means requirement developers should factor into the system design the necessity of refueling/recharging using the same scenarios that are used to illustrate other performance requirements, and allowing the adversary a realistic chance to interdict the refueling/recharging effort. Systems Engineers may find it necessary to have a continuing dialogue with the warfighter (the user and requirements developer) to help grasp the operational impact of these issues and depict them in trade space decisions.

Energy-related engineering analysis should begin early enough to support initial Analysis of Alternatives (AoA) planning following the Materiel Development Decision, and should also be routinely updated to inform any AoA performed later in the life cycle (i.e., in support of block upgrades and modifications).

The following documents provide the Program Manager and Systems Engineer with additional insight into the issue of Operational Energy in the acquisition life cycle:

- CJCSI 3170.01H (for the Energy Key Performance Parameter)
- Joint Capabilities Integration and Development System (JCIDS) Manual (requires Common Access Card (CAC) to access website)
- Operational Energy Strategy: Implementation Plan
- Defense Science Board Task Force report on Operational Energy, February 2008
- Defense Science Board Task Force report on Operational Energy, May 2001

NOTE: The results of the sustainability analysis (see DAG section 4.3.19.2. Sustainability Analysis) can be used to inform energy analyses.

4.3.18.17. Packaging, Handling, Storage, and Transportation

4.3.18.17. Packaging, Handling, Storage, and Transportation

The program team employs Packaging, Handling, Storage, and Transportation (PHS&T) principles/methods to ensure the necessary equipment reaches the warfighter while minimizing risk of damage to the equipment during handling, storage, and transportation - frequently in highly challenging and corrosive operational environments.

Thorough PHS&T requirements promote supportability and sustainability of major end items,

reparable system elements, and supporting test equipment. PHS&T focuses on transportation, handling, and storage constraints on performance resulting from driving size, weight, parts robustness, and shelf life.

Program Managers and Systems Engineers should ensure PHS&T is addressed during the requirements analysis process, and validated throughout each phase of the systems engineering (SE) development of the weapon system. DoDI 4540.07 identifies specifics regarding PHS&T as related to program management of weapon systems acquisitions. In addition, the following documents address PHS&T:

- MIL-STD-2073-1E, Department of Defense Standard Practice for Military Packaging
- MIL-STD-129P, Military Marking for Shipment and Storage
- ASTM-D3951, Standard Practice for Commercial Packaging
- DOD 4140.27-M, Self-Life Item Management Manual
- DTR 4500.9-R, Defense Transportation Regulation
- Title 49 of the Code of Federal Regulations (49 CFR)

4.3.18.18. Producibility, Quality, and Manufacturing Readiness

4.3.18.18.1. Producibility

4.3.18.18.2. Quality in Design

4.3.18.18.3. Assessing Manufacturing Readiness and Risk

4.3.18.18. Producibility, Quality, and Manufacturing Readiness

4.3.18.18.1. Producibility

Producibility (the relative ease of manufacturing), like manufacturing and other key system design functions, is integral to effectively and efficiently delivering capability to the warfighter. Producible designs are lower risk, more cost-effective, and repeatable, which enhances product reliability and supportability. Producibility should be assessed at both a product and enterprise (i.e., organizational) level. The Program Manager should implement producibility engineering and planning efforts early and should continuously assess the integrated processes and resources needed to successfully achieve producibility.

To assess producibility on a product level, both the product and its manufacturing processes should be measured. Manufacturing processes should be monitored and controlled, through measurement, to ensure that they can repeatedly produce accurate, high-quality products, which helps the program meet objectives for limiting process variability to a tolerable range.

To assess producibility within a manufacturing enterprise level, the organization should evaluate producibility performance on a product-specific basis. This evaluation allows the organization to better understand the strengths and weaknesses of its producibility approach, so that enhancements can be identified and measures of processes, products, and the producibility

system (integrated processes and resources needed for achieving producibility) can be tailored to strive for continuous improvement.

The Program Manager should ensure that the producibility program focuses on the following five elements to build and maintain a successful producibility system:

1. Establish a producibility infrastructure:

- Organize for producibility
- Integrate into the program's risk management program
- Incorporate producibility into the new product strategy
- Employ producibility design guidelines

2. Determine Process Capability:

- Determine Process Capability (Cpk)
- Understand and document company and supplier processes
- Plan for future process capabilities

3. Address producibility during initial design efforts:

- Identify design objectives
- Identify key characteristics of the design
- Perform trade studies on alternative product and process designs
- Develop a manufacturing plan
- Perform complexity analysis

4. Address producibility during detailed design:

- Address producibility measurements at Preliminary Design Review (PDR), Critical Design Review (CDR), Production Readiness Review (PRR), and Full-Rate Production Design Review (FRP DR)
- Optimize manufacturing plans as the design matures

5. Measure producibility processes, products and systems.

Producibility should be a Technical Performance Measure (TPM) for the program, and the program's strategy for producibility should be contained in paragraph 3.6 of the program's Systems Engineering Plan (SEP). Planned producibility engineering activities for previous and subsequent phases also should be summarized in the SEP. As a key design accomplishment, producibility should be included in the SEP, mapping key design considerations into the RFP and subsequently into the contract.

4.3.18.18.2. Quality in Design

Design engineering focuses on concurrent development of the total system using capable

manufacturing processes leading to a producible, testable, sustainable and affordable product that meets defined requirements. The design phase is critical because product life-cycle costs are committed at this point. The objectives of quality design efforts are to:

- Achieve effective and efficient manufacturing with necessary process controls to meet system requirements
- Transition to production with no significant manufacturing process and reliability risks that could breach production thresholds for cost and performance

To ensure consistency in applying quality planning and process control, the program should establish Quality Management Systems (QMS) early (Milestone A). The QMS should be defined and documented in paragraph 11.2 of the Technology Development Strategy (TDS) and the Acquisition Strategy (AS). The process should be integrated into these documents as a systems engineering (SE) practice that supports the successful transition of capability development to full-rate production and delivery of systems to support warfighter missions.

The primary focus of the QMS should be to ensure efficiency in processes; when integrated with Statistical Process Control (SPC) (eliminate defects and control variation) the transition from system development to production should help with controlling life-cycle cost and reducing complexities that are often found when quality is not integrated as a function of the design. Therefore, to achieve high-quality (product characteristics meet specification requirements), an end product should be designed so:

- Processes to produce the end product are in statistical control (uniformity in manufacturing and production)
- Design specifications are aligned with manufacturing process capabilities
- Functional design integrates producibility requirements (measure of relative ease of manufacturing) with no significant compromises to quality and performance

The Program Manager and Systems Engineer should take into consideration that process capability goes beyond machine capability. The process should include the effects of change in workers, materials, fabrication methods, tooling and equipment, setup, and other conditions. Process capability data should be collected throughout process and product development. Data collection efforts should be continuously refined, using test articles, through production.

In addition to QMS and SPC, understanding and improving processes may require common and/or new tools and techniques to eliminate defects and variation in processes.

Another quality management tool available to the program management team is parts management. MIL-STD-3018 provides requirements for the implementation of an effective Parts Management Program (PMP) on Department of Defense (DoD) acquisitions.

Quality should be a TPM for the program, and the program's strategy for managing quality should be included in the SEP. Planned quality engineering and management activities for previous and subsequent phases also should be summarized in the SEP. As a key design accomplishment, quality should be included in the SEP (Table 4.6-1) mapping key design

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considerations into contracts.

Two valuable tools to assist in creating quality in design are Six Sigma and Quality Function Development (QFD). Six Sigma techniques identify and reduce all sources of product variation - machines, materials, methods, measurement system, the environment, and the people in the process. QFD is a structured approach to understanding customer requirements and translating them into products that satisfy those needs.

4.3.18.18.3. Assessing Manufacturing Readiness and Risk

Manufacturing feasibility, processes, and risk should be assessed early (Materiel Solution Analysis (MSA) phase) and continuously through the Production and Deployment (P&D) phase on all acquisition programs. To ensure integration of manufacturing readiness and risk as part of design activities, the focus should be on system risk reduction, manufacturing process reliability, and producibility.

Program Managers should use existing manufacturing processes whenever practical to support low-risk manufacturing. When the design requires new manufacturing capability, the Program Manager may need to consider new manufacturing technologies or process flexibility (e.g., rate and configuration insensitivity), which introduces risk. DoDI 5000.02, Enclosure 2, defines the requirements for manufacturing processes and manufacturing risks. See DFARS 207.105, Contents of Written Acquisition Plans, for specific guidance on manufacturing actions planned by the Program Manager to execute the approach established in the Acquisition Strategy (AS) and to guide contractual implementation. These include:

- Consideration of requirements for efficient manufacture during the design and production of the system
- The availability of raw materials, special alloys, composite materials, components, tooling, and production test equipment
- The use of advanced manufacturing technology, processes, and systems
- The use of contract solicitations that encourage competing offerors to acquire modern technology, production equipment, and production systems (including hardware and software)
- Methods to encourage investment in advanced manufacturing technology, production equipment, and processes
- During source selection, increased emphasis on the efficiency of production
- Expanded use of commercial manufacturing processes rather than processes specified by DoD

Low-risk manufacturing readiness includes early planning and investments in producibility requirements, manufacturing process capabilities, and quality management to ensure effective and efficient manufacturing and transition to production. It also includes assessments of the industrial base. Manufacturing risk is evaluated through manufacturing readiness assessments, which are integrated with existing program assessments throughout the acquisition life cycle.

The Program Manager should assess manufacturing readiness in the program's earliest phase and the assessment should be continuous. The Program Manager should report on the program's manufacturing readiness progress/status during each system's engineering technical review, Program Support Review, or their equivalent, and before each milestone decision.

Successful manufacturing has many dimensions. Industry and Government have identified best practices in the following nine manufacturing risk categories. Program Managers should use the best practices to assess their programs early and should report on these areas during technical reviews and before acquisition milestones. Implementation of these best practices should be tailored according to product domains, complexity and maturity of critical technologies, manufacturing processes, and specific risks that have been identified throughout the assessment process. These categories should help frame the risk assessment and focus mitigation strategies:

- Technology and the Industrial Base: assess the capability of the national technology and industrial base to support the design, development, production, operation, uninterrupted maintenance support, and eventual disposal (environmental impacts) of the system
- Design: assess the maturity and stability of the evolving system design and evaluate any related impact on manufacturing readiness
- Cost and Funding: examine the risk associated with reaching manufacturing cost targets
- Materials: assess the risks associated with materials (including basic/raw materials, components, semi-finished parts, and subassemblies)
- Process Capability and Control: assess the risks that manufacturing processes are able to reflect the design intent (repeatability and affordability) of key characteristics
- Quality Management: assess the risks and management efforts to control quality and foster continuous improvement
- Manufacturing Workforce (Engineering and Production): assess the required skills, certification requirements, availability, and required number of personnel to support the manufacturing effort
- Facilities: assess the capabilities and capacity of key manufacturing facilities (prime, subcontractor, supplier, vendor, and maintenance/repair)
- Manufacturing Management: assess the orchestration of all elements needed to translate the design into an integrated and fielded system (meeting program goals for affordability and availability)

As part of the manufacturing strategy development effort, the Program Management team needs to understand the contractor/vendor business strategy and the impacts to Government risk identification and mitigation efforts, such as the Make/Buy decisions. Additional guidance on assessing manufacturing risks can be found in the Manufacturing Readiness Guide.

Assessment and mitigation of manufacturing risk should begin as early as possible in a program's acquisition life cycle-including conducting a manufacturing feasibility assessment as part of the AoA.

The Program Manager and Systems Engineer should consider the manufacturing readiness and manufacturing-readiness processes of potential contractors and subcontractors as a part of the

source selection for major defense acquisition programs, see DFARS 215.304.

The Program Manager and Systems Engineer should assess manufacturing readiness at a minimum of four key points (events) during the acquisition life cycle, as described in Table 4.3.18.18.3.T1.

Table 4.3.18.18.3.T1. Minimum Points (Events) to Assess Manufacturing Readiness during the Acquisition Life Cycle

Manufacturing Readiness Assessment Points	Considerations
1. Post-AoA assessment during the Materiel Solution Analysis Phase. As part of the AoA, manufacturing risks should have been assessed for each of the competing alternatives (see the MRL Implementation Guide for one source of specific assessment factors). Risks for the preferred system concept should be assessed and identified at this point. The overall assessment should consider whether:	• Program critical technologies are ready for the Technology Development phase • Required investments in manufacturing technology development have been identified • Processes to ensure manufacturability, producibility, and quality are in place and are sufficient to produce prototypes. Manufacturing risks and mitigation plans are in place for building prototypes • Cost objectives have been established and manufacturing cost drivers have been identified; draft Key Performance Parameters have been identified as well as any special tooling, facilities, material handling, and skills required • Producibility assessment of the preferred system concept has been completed, and the industrial base capabilities, current state of critical manufacturing processes, and potential supply chain sources have all been surveyed

Manufacturing Readiness Assessment Points	Considerations
2. Technology Development, Pre-EMD Review. As the program approaches the Pre-EMD Review and the Milestone B decision, critical technologies should have matured sufficiently for 2366b certification and demonstrated in a relevant environment and should consider:	• The program should be nearing acceptance of a preliminary system design • An initial manufacturing approach has been developed • Manufacturing processes have been defined and characterized, but there are still significant engineering and/or design changes in the system itself; manufacturing processes that have not been defined or that may change as the design matures should be identified • Preliminary design, producibility assessments, and trade studies of key technologies and components should have been completed • Prototype manufacturing processes and technologies, materials, tooling and test equipment, as well as personnel skills have been demonstrated on systems and/or subsystems in a production-relevant environment • Cost, yield, and rate analyses have been performed to assess how prototype data compare with target objectives, and the program has in place appropriate risk reduction to achieve cost requirements or establish a new baseline, which should include design trades • Producibility considerations should have shaped system development plans, and the Industrial Base Capabilities assessment (in the Acquisition Strategy (AS) for Milestone B has confirmed the viability of the supplier base
3. Production Readiness Review. A production readiness review identifies the risks of transitioning from development to production. Manufacturing is a function of production; in order to transition to production without significant risk it is important that key processes have been considered and evaluated during the PRR, such as ensuring:	• The detailed system design is complete and stable to support low-rate production • Technologies are mature and proven in a production environment, and manufacturing and quality processes are capable, in control and ready for low-rate production • All materials, manpower, tooling, test equipment, and facilities have been proven on pilot lines and are available to meet the planned low-rate production schedule • Cost and yield and rate analyses are updated with pilot line results • Known producibility risks pose no significant challenges for low-rate production • Supplier qualification testing and first article inspections have been completed • Industrial base capabilities assessment for Milestone C has been completed and shows that the supply chain is adequate to support LRIP

Manufacturing Readiness Assessment Points	Considerations
4. FRP Decision Review. To support FRP, there should be no significant manufacturing process and reliability risks remaining. Manufacturing and production readiness results should be presented that provide objective evidence of manufacturing readiness. The results should include recommendations for mitigating any remaining low (acceptable) risk, based on assessment of manufacturing readiness for FRP which should include (but not be limited to):	• LRIP learning curves that include tested and applied continuous improvements • Meeting all systems engineering (SE)/design requirements • Evidence of a stable system design demonstrated through successful test and evaluation • Evidence that materials, parts, manpower, tooling, test equipment, and facilities are available to meet planned production rates • Evidence that manufacturing processes are capable, in control, and have achieved planned FRP objectives • Plans are in place for mitigating and monitoring production risks • LRIP cost targets data have been met; learning curves have been analyzed and used to develop the FRP cost model

4.3.18.19. Reliability and Maintainability Engineering

4.3.18.19. Reliability and Maintainability Engineering

The purpose of Reliability and Maintainability (R&M) engineering (Maintainability includes Built-In-Test (BIT)) is to influence system design in order to increase mission capability and availability, and decrease logistics burden and cost over a system's life cycle. Properly planned, R&M engineering reduces cost and schedule risks by preventing or identifying R&M deficiencies early in development. This early action results in increased acquisition efficiency and higher success rates during operational testing, and can even occur in the development process as early as the Engineering and Manufacturing Development (EMD) phase.

DoDI 5000.02 requires Major Defense Acquisition Program (MDAP) Program Managers to implement a comprehensive R&M engineering program as an integral part of the systems engineering (SE) process. The Systems Engineer should understand that R&M parameters have an impact on the system's performance, availability, logistics supportability, and total ownership cost. To ensure a successful R&M engineering program, the Systems Engineer should integrate the following activities across the program's engineering organization and processes:

- Providing adequate R&M staffing
- Ensuring R&M engineering is fully integrated into SE activities, Integrated Product Teams, and other stakeholder organizations (i.e., Logistics, Test, and ESOH)
- Ensuring specifications contain realistic quantitative R&M requirements traceable to the Initial Capabilities Document (ICD)/Capability Development Document (CDD) /Capability Production Document (CPD)
- Ensuring that R&M engineering activities and deliverables in the Request for Proposal are appropriate for the program phase and product type

- Integrating R&M engineering activities and reliability growth planning curve(s) in the Systems Engineering Plan (SEP) at each milestone
- Planning verification methods for each R&M requirement
- Ensuring the verification methods for each R&M requirement are described in the TEMP, along with a reliability growth planning curve beginning at MS B
- Ensuring data from R&M analyses, demonstrations, and tests are properly used to influence life-cycle product support planning, availability assessments, cost estimating, and other related program analyses
- Identifying and tracking R&M risks and Technical Performance Measures.
- Assessing R&M status during program technical reviews
- Including consideration of R&M in all configuration changes and trade-off analyses

As part of the SE process, the R&M engineer should be responsible for the R&M activities by acquisition phase outlined in Table 4.3.18.19.T1.

Table 4.3.18.19.T1. R&M Activities by Acquisition Phase

Acquisition Phase	R&M Activities
Materiel Solution Analysis (MSA) Phase. During the Materiel Solution Analysis Phase, the R&M engineer, as part of the program SE team, should:	• Analyze conceptual design approaches and estimate the feasibility with respect to R&M ICD performance capabilities • Perform AoA trade-off studies among R&M, availability, and other system performance parameters to arrive at a preferred system alternative. The studies should be performed in conjunction with product support, cost, and design personnel, using the DoD RAM-C Rationale Report Manual • Prepare the Reliability, Availability, Maintainability, and Cost (RAM-C) Rationale Report and attach it to the SEP • Translate ICD performance capabilities and draft CDD thresholds to R&M specification requirements based on system use conditions, mission profile, failure definitions, and utilization rates • Define contractor R&M engineering activities in the RFP and contract Statement of Work for the TD phase, which should include: a. Allocations b. Block diagrams and modeling c. Predictions d. Failure Mode, Effects, and Criticality Analysis (FMECA) e. Subsystem and system-level reliability growth planning activities f. R&M tests and demonstrations g. Failure Reporting, Analysis, and Corrective Action System (FRACAS)

Acquisition Phase	R&M Activities
Technology Development (TD) Phase. During the Technology Development phase, the R&M engineer, as part of the program SE team, should:	• Participate in trade studies during requirements analysis and architecture design • Review results of R&M engineering analyses, verification tests, design approach, availability assessments, and maintenance concept optimization to verify conformance to requirements, and to identify potential R&M problem areas • Contribute to integrated test planning to avoid duplication and afford a more complete utilization of all test data for R&M assessment. Comprehensive test planning should include subsystem reliability growth and maintainability and Built-In Test (BIT) demonstrations as appropriate • Verify that plans have been established for the selection and application criteria of parts, materials, and processes to limit reliability risks • Define contractor R&M engineering activities in the RFP and contract Statement of Work for the EMD phase, during which R&M quantitative requirements and verification methods are incorporated
Engineering and Manufacturing Development (EMD) Phase. During the EMD phase, the R&M engineer, as part of the program SE team, should:	• Perform evaluations to assess R&M status and problems • Ensure that the product baseline design and required testing can meet the R&M requirements • Ensure the final FMECA identifies failure modes, and their detection methods, that could result in personnel injury and/or mission loss, and ensure they are mitigated in the design • Ensure that the detailed R&M prediction to assess system potential to meet design requirements is complete • Verify through appropriate subsystem/equipment-level tests the readiness to enter system-level testing at or above the initial reliability established in the reliability growth-planning curve in both the SEP and the TEMP • Verify system conformance to specified R&M requirements through appropriate demonstration and test • Implement a FRACAS to ensure feedback of failure data during test and to apply and track corrective actions • Coordinate with the Chief Developmental Tester (T&E Lead) and Operational Test Agencies (OTA) to ensure that the program office and OTA data collection agree on R&M monitoring and failure definitions, and that R&M and BIT scoring processes are consistent in verification of requirements through all levels of testing • Define contractor R&M engineering activities in the RFP and contract Statement of Work (SOW) for the P&D phase to ensure adequate R&M engineering activities take place during P&D, and to ensure the RFP and contract SOW provide adequate consideration of R&M in re-procurements, spares, and repair parts • Verify that parts, materials, and processes meet system requirements through the use of a management plan detailing reliability risk considerations and evaluation strategies for the intended service life. Include flow of requirements to subcontractors and suppliers. See MIL-STD-1546, Parts, Materials, and Processes Control Program for Space and Launch Vehicles, and MIL-STD-1547, Electronic Parts, Materials, and Processes for Space and Launch Vehicles

Acquisition Phase	R&M Activities
Production and Deployment (P&D) Phase. During the P&D phase, the R&M engineer, as part of the programs SE team should:	• Verify initial production control of R&M degradation factors by test and inspection, production data analysis, and supplemental tests • Verify R&M characteristics, maintenance concept, repair policies, Government technical evaluation, and maintenance procedures by T&E • Identify R&M and production-related BIT improvement opportunities via FRACAS and field data assessment • Review Engineering Change Proposals (ECP), operational mission/deployment changes, and variations for impact on R&M • Update R&M predictions and FMECAs based on field results and apply them to the models previously developed to assess impacts on spares, manpower, missions, and availability • Verify that parts, materials, and processes management requirements for limiting reliability risk and "lessons learned" are utilized during all design change efforts including change proposals, variations, substitutions, product improvement efforts, or any other hardware change effort
Operations and Support (O&S) Phase. During the O&S phase, the R&M engineer, as part of the program SE team should:	• Assess operational data to determine the adequacy of R&M and BIT characteristics performance, maintenance features and procedures, and provisioning plans • Identify problem areas for correction through ongoing closed-loop FRACAS and field data assessment • Monitor availability rates and respond to negative trends and data anomalies

4.3.18.20. Spectrum Management

4.3.18.20. Spectrum Management

Warfighters use spectrum-dependent systems for communications, sensors (i.e., radar), navigation beacons, jammers, homing devices, anti-Improvised Explosive Devices (IED), and other purposes. Often emitters are in close physical proximity to each other and to civilian devices that should not be disrupted by military signals. Spectrum-dependent system developers should be aware of the enemy electronic order of battle and countermeasures, and plan accordingly. Devices (including commercial items) that do not account for countermeasures may have vulnerabilities in hostile environments.

Spectrum management requirements are needed for all spectrum-dependent systems. Any system that uses an antenna or a platform that mounts such systems is a spectrum-dependent system. If a platform obtains a spectrum-dependent system as Government-furnished equipment (GFE), the platform Program Manager is responsible for ensuring that the GFE Program Manager has obtained the needed permissions. Both programs are required to submit a Spectrum Supportability Risk Assessment (SSRA). The platform SSRA can reference the GFE SSRA, but may have to expand upon it regarding host nation features or other information not contained in the GFE-level SSRA. The Systems Engineer should be aware of the worldwide rules for spectrum management and the need to obtain host nation permission for each transmitter and frequency assignment.

Program Managers need to ensure that spectrum access is adequate and that it is granted in the Continental United States (CONUS) and wherever else the equipment is deployed. The Pre-Milestone A Analysis of Alternatives (AoA) should address spectrum needs as part of concept formulation. Both the SSRA and DD-1494 are required for each milestone (see DoDI 4650.01). The SSRA is used within the DoD as the basis for assessing the feasibility of building and fielding equipment that operate within assigned frequency bands and to identify potential de-confliction situations. The DD-1494, Application for Equipment Frequency Allocation, has four stages, which reflect the increasing maturity of available spectrum information during development. The DD-1494 form is submitted to National Telecommunications and Information Administration (NTIA) for approval of spectrum allocation without which emitters cannot operate within CONUS, and to the International Telecommunications Union (ITU) for satellites. The NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management (Redbook) chapter 3 addresses international treaty aspects of the spectrum and chapter 4 addresses frequency allocations.

The Systems Engineer has a lead role in defining spectrum needs, throughput and power requirements, and other attributes of the signals in space (outside the antenna - not in the transmission device) and the antenna characteristics and platform mounting details, as well as the safety aspects of emitters with regard to the Hazards of Electromagnetic Radiation to Ordnance (HERO), Personnel (HERP), and Fuel (HERF). The SE should be aware that portions of the spectrum previously assigned to DoD or other Federal users are being sold for commercial use. Thus, previously approved DD-1494 can be revoked, requiring modifications to designs, and even to fielded equipment. Similarly, host nations can alter prior agreements as commercial applications encroach upon previously available spectrum.

Each nation reserves the right to control emitters operating within its territory, thus host nation agreements are essential in support of deployment. Program Managers and Systems Engineers of platforms that mount multiple emitters and receivers need to obtain spectrum access for each emitter and ensure that those emitters and receivers do not produce mutual interference, or interact with ordnance (see DoDD 3222.3, MIL-STD-461, MIL STD-464, and MIL-HDBK-235-1, 237,and 240A, and "Joint Services Guide for Development of a Spectrum Supportability Risk Assessment"). The Defense Information Systems Agency (DISA), Defense Spectrum Organization provides spectrum support and planning for DoD and can be reached at http://www.disa.mil/Services/Spectrum. See Figure 4.3.18.20.F1 for spectrum activities by acquisition phase. This figure summarizes the requirements of DoDI 4650.01.

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Figure 4.3.18.20.F1. Spectrum-Related Activities by Life-Cycle Phase

Defense Acquisition Life Cycle Phase	A Materiel Solution Analysis	B Technology Development	C Engineering & Manufacturing Development	FRP/FD Production & Deployment	Operations & Support
Spectrum Supportability Risk Assessment (SSRA)	Prepare SSRA	Update SSRA	Update SSRA	Update SSRA	Update SSRA for mission & technical changes
DD-1494, Application for Equipment Frequency Allocation	Stage 1 (Conceptual)	Stage 2 (Experimental)	Stage 3 (Developmental) NTIA approval needed before transmission tests	Stage 4 (Operational) NTIA approval needed before deployment or when changes occur	
Program Management, Systems Engineering, and Testers Electromagnetic Environmental Effects (E3) Tasks	E3 assessment for SSRA	Update E3 assessment for SSRA	Update E3 assessment for SSRA	Update E3 assessment for SSRA	Resolve interference
	Define EME & E3 requirements (i.e., frequency bands, throughput, power, operational areas, etc.)	Update EME; Prepare E3 inputs to ISP, TEMP and acquisition documents; Address at PDR	E3 & EME inputs to TEMP & ISP; HERO, HERP, HERF, TEMPEST, & EMI address at CDR; DT&E transmission tests after Stage 3 approval	Conduct OT&E tests including E3 tests IAW TEMP; E3 assessment report	Deployed support
	Consider host nation (HN) constraints	Obtain HN comments via SMO	Begin HN discussions via SMO	Obtain HN approval before deployment	Maintain HN approval

CDR – Critical Design Review
DT&E – developmental test and evaluation
E3 – electromagnetic environmental effects
EME – electromagnetic environment
EMI – electromagnetic interference
ISP – Information Support Plan
HERF – hazard of electromagnetic radiation on fuel
HERO – hazard of electromagnetic radiation on ordnance
HERP – hazard of electromagnetic radiation on personnel
HN – host nation
IAW – in accordance with
NTIA – National Telecommunications and Information Administration
OT&E – operational test and evaluation
PDR – Preliminary Design Review
SMO – spectrum management office
SSRA – spectrum supportability risk assessment
T&E – test and evaluation
TEMP – Test and Evaluation Master Plan

4.3.18.21. Standardization

4.3.18.21. Standardization

Standardization supports the achievement of commonality and interoperability of parts and processes with United States forces and our allies, promote safety, provide for life-cycle sustainment, and allow for rapid, cost-effective technology insertion through use of standard interfaces and open systems. Standardization is an enabling tool to provide the warfighter with systems and equipment that are interoperable, reliable, sustainable and affordable. Standardization plays a key role in defining systems engineering (SE) best practices and processes.

The Program Manager balances the decision to use standardized agreements, practices, products, parts, processes, interfaces, and methods with required capabilities, operational environment, technology feasibility and growth, and cost-effectiveness.

DoD 4120.24-M, Chapter 3, Standardization in the Acquisition Process, provides policies on when to standardize, how to document standardization decisions, and a discussion of the tailoring of standardization documents through rewriting, extracting, or eliminating requirements.

Parts management is a standardization design strategy available to Program Managers. Benefits of parts standardization include:

- Reducing the number of unique or specialized parts used in a system (or across systems)
- Reducing the logistics footprint
- Lowering life-cycle costs

In addition, parts management can enhance the reliability of the system and mitigate part obsolescence due to Diminishing Manufacturing Sources and Material Shortages (DMSMS). MIL-STD-3018, Parts Management, dictates that program offices should apply standardization processes to:

- Improve parts commonality
- Reduce total ownership costs
- Reduce proliferation of parts
- Promote the use of parts with acceptable performance, quality, and reliability

The Systems Engineer is responsible for:

- Implementing parts management contractual requirements
- Approving contractor submitted plans
- Ensuring parts management objectives are met

Additional guidance on parts management may be found in SD-19, Parts Management Guide.

4.3.18.22. Supportability

4.3.18.22. Supportability

Supportability refers to the inherent characteristics of the system and the enabling system elements that allow effective and efficient sustainment (including maintenance and other support functions) throughout the system's life cycle. By addressing supportability as part of the system design, the Program Manager through the Systems Engineer and Product Support Manager ensures the system reaches Initial Operational Capability (IOC) with the required enabling system elements in place. The benefits to the program are:

- Cost savings
- Fielding of a more affordable logistics infrastructure
- Improving Materiel and Operational Availability
- Reducing footprint

Early consideration of supportability needs during Requirements Analysis, Architecture Design, and Implementation processes are critical to ensure the delivered capability is operationally suitable, effective, sustainable, and affordable. The system baseline should incorporate inherent supportability characteristics and should include the design of the enabling support infrastructure. Details can be found in DAG Chapter 5 Life-Cycle Logistics, but typical product

support infrastructure considerations are listed in Table 4.3.18.22.T1.

Table 4.3.18.22.T1. Product Support Infrastructure Considerations

Infrastructure Elements	Typical Considerations
Manpower and Personnel	Specifically support personnel for installation, checkout, sustaining support and maintenance
Training and Training Support	For the system operators and for system maintenance personnel
Supply Support	Including repairable and non-repairable spares, consumables, and special supplies
Support Equipment	Including tools, condition and state monitoring, diagnostic and checkout, special test and calibration equipment
Computer Resources	Operating systems and software supporting logistics functions and associated infrastructure
Packaging, Handling, Storage, and Transportation	Special provisions, containers and transportation needs
Facilities and Infrastructure	Including facilities to support logistics and sustainment actions at all levels
Technical Data	Including system installation and checkout procedures; operating and maintenance instructions and records; alteration and modification instructions, etc.

The Program Manager is responsible for approving life-cycle cost trades throughout the acquisition process. It is critical that the design of a program focused on life-cycle supportability involve the logisticians alongside the end users early in the Stakeholder Requirements Definition process to support the Reliability Centered Maintenance (RCM) analysis and to develop the overall performance based product support strategy. Reference DoD 4151.22-M, Conditioned Based Maintenance Plus (CBM+), an important support concept and a specific initiative, can be useful to perform maintenance based on evidence of need as provided by RCM analysis and other enabling processes and technologies.

RCM analysis is a systematic approach analyzing the functions and potential failures to identify and define preventive or scheduled maintenance tasks for an equipment end item. Tasks may be preventive, predictive, or proactive in nature. RCM results provide operational availability with an acceptable level of risk in an efficient and cost-effective manner.

Additionally, the Product Support Manager and Systems Engineer should ensure that supportability activities are documented in the Systems Engineering Plan (SEP) and the Life-Cycle Support Plan (LCSP), and that the supportability design requirements are documented in the program's functional baseline.

The Systems Engineer working with the Product Support Manager should identify and mitigate the supportability life-cycle cost drivers to ensure a system is affordable across the life cycle. The streamlined LCSP outline calls out specific phase and milestone expectations. These

expectations include determining supportability design alternatives along with their associated cost and establishing both the Operational Availability (A_O) and Materiel Availability (A_M) drivers. The derived supportability requirements should be based on trade studies along with their associated cost and operational and materiel availability drivers (see DAG Chapter 5 Life-Cycle Logistics). The Cost-Benefit Analyses, jointly conducted by the Systems Engineer and Product Support Manager in the supportability analysis, provides insight into supportability drivers and includes the impact of resources on readiness supported by engineering analyses required for product support (i.e., FMECA, predictions, and diagnostics architecture).

Supportability analysis is an iterative activity conducted during the system's development, and is used by the Program Manager and Product Support Manager to define the system's support and document the support in the program's LCSP. Supportability analysis begins in stakeholder requirements definition, as part of the Analysis of Alternatives (AoA), and continues through the design, test and evaluation, production and deployment activities/phases of the system. The supportability analysis and the resultant product support package mature in parallel with the maturity and evolution of the design, and should be documented in an integrated data/decision environment.

4.3.18.23. Survivability and Susceptibility

4.3.18.23. Survivability and Susceptibility

A system with a balanced survivability and susceptibility approach ensures operational crew and personnel safety while satisfying mission effectiveness and operational readiness requirements.

Survivability is the capability of a system and its crew to avoid or withstand a hostile environment without suffering an abortive impairment of its ability to accomplish its designated mission. Susceptibility is the degree to which a device, piece of equipment, or weapon system is open to effective attack as a result of one or more inherent weaknesses. Man-made and natural environmental conditions, described in MIL-STD-810 (sand, vibration, shock, immersion, fog, etc.), and electromagnetic environment, described in MIL-STD-461/464, also should be considered in system design.

Susceptibility is a function of operational tactics, countermeasures, probability of an enemy threat, etc. Susceptibility is considered a subset of survivability. Vulnerability is the characteristics of a system that cause it to suffer a definite degradation (loss or reduction of capability to perform the designated mission) as a result of having been subjected to a certain (defined) level of effects in an unnatural (man-made) or natural (e.g., lightning, solar storms) hostile environment. Vulnerability is also considered a subset of survivability.

Design and testing ensure that the system and crew can withstand man-made hostile environments without the crew suffering acute chronic illness, disability, or death. The Program Manager, supported by the Systems Engineer, should fully assess system and crew survivability against all anticipated threats, at all levels of conflict, throughout the system life cycle. The goal of survivability and susceptibility is to:

- Provide mission assurance while maximizing warfighter safety (or minimizing their exposure to threats)
- Incorporate balanced survivability, with consideration to the use of signature reduction with countermeasures
- Incorporate susceptibility reduction features that prevent or reduce engagement of threat weapons
- Provide mission planning and dynamic situational awareness features

The mandatory Survivability Key Performance Parameter (KPP) is applicable to all capability documents for manned systems and may be applicable to unmanned systems. The intent of the Survivability KPP includes:

- Reducing a system's likelihood of being engaged by hostile fire, through attributes such as speed, maneuverability, detectability, and countermeasures
- Reducing the system's vulnerability if hit by hostile fire, through attributes such as armor and redundancy of critical components
- Allowing the system to survive and continue to operate in a chemical, biological, radiological, and nuclear (CBRN) environment, if required

If the system or program has been designated by the Director, Operational Test and Evaluation (DOT&E), for live-fire test and evaluation (LFT&E) oversight, the Program Manager should integrate test and evaluation (T&E) to address crew survivability issues into the LFT&E program supporting the Secretary of Defense LFT&E Report to Congress.

If the system or program has been designated a CBRN mission-critical system, the Program Manager should address CBRN survivability, in accordance with DoDI 3150.09, The Chemical, Biological, Radiological, and Nuclear (CBRN) Survivability Policy. The Program Manager should ensure that progress toward CBRN survivability requirements is documented in the applicable Service CBRN mission-critical report.

Unless waived by the Milestone Decision Authority (MDA), mission-critical systems, including crew, regardless of acquisition category, should be survivable to the threat levels anticipated in their projected operating environment as portrayed in their platform-specific System Threat Assessment Report (STAR) (see DoDI 5000.02, Enclosures 6 and 8), or in lieu of a STAR, the appropriate capstone threat document.

The Systems Engineer should describe in the Systems Engineering Plan:

- How the design incorporates susceptibility and vulnerability reduction and CBRN survivability requirements
- How progress toward these are tracked over the acquisition life cycle

Additional techniques include rapid reconstruction (reparability) to maximize wartime availability and sortie rates and incorporating damage tolerance in the system design.

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4.3.18.24. System Security Engineering

4.3.18.24. System Security Engineering

System Security Engineering (SSE) activities allow for identification and incorporation of security design and process requirements into risk identification and management in the requirements trade space.

SSE is the integrating process for mitigating and managing risks to advanced technology and mission-critical system functionality from foreign collection, design vulnerability or supply chain exploit/insertion, battlefield loss, and unauthorized or inadvertent disclosure throughout the acquisition life cycle. The SSE process captures SSE analysis in the system requirements and design documents, and SSE verification in the test plans, procedures, and results documents. The Program Protection Plan (see DAG Chapter 13 Program Protection) documents the comprehensive approach to system security engineering analysis and the associated results.

SSE is the functional discipline within systems engineering that ensures security requirements are included in the engineering analysis with the results being captured in the Program Protection Plan (PPP), provided at each Systems Engineering (SE) technical review (SETR) event (see DAG Chapter 13 Program Protection) and incorporated into the SETR-related SE requirements and the functional, allocated, and product baselines. The PPP is approved by the Milestone Decision Authority (MDA) at each milestone decision review and at the Full-Rate Production/Full-Deployment (FRP/FD) decision, with an approvable draft at the pre-Engineering and Manufacturing Development (EMD) review. The analysis should be used to update the SE baselines prior to each SETR and key knowledge point throughout the life cycle.

The Program Manager is responsible for developing a PPP that ensures the program complies with program protection policy and system requirements. The Systems Engineer and/or System Security Engineer is responsible for ensuring a balanced set of security requirements, designs, testing, and risk management are incorporated and addressed in the their respective trade spaces.

The Systems Engineer and/or System Security Engineer is responsible for facilitating cross-discipline system security working groups and is typically responsible for leading the SSE analysis necessary for development of the PPP. The cross-discipline interactions reach beyond the SSE community to the test and logistics communities. The Test Lead is responsible for incorporating sufficient system security test requirements into the Test and Evaluation Strategy (TES) and Test and Evaluation Master Plan (TEMP). The logistics community is responsible for continuing the protections and risk management activities initiated in acquisition throughout the Operations and Support (O&S) phase.

SSE processes inform the development and release of each request for proposal (RFP) (see DAG Chapter 13 Program Protection) by incorporating SSE process requirements into the Statement of Work (SOW) and the system security requirements into the Requests for Proposal (RFP) requirements document. Contractor responsibilities include developing plans to ensure that the system security protections are implemented in the development environments, system designs, and supply chains. The early and frequent consideration of SSE principles reduces rework and

expense resulting from late-to-need security requirements (e.g., anti-tamper, exportability features, supply chain risk management, secure design, defense-in-depth, and information assurance implementation).

4.3.19. Tools, Techniques, and Lessons Learned

4.3.19. Tools, Techniques, and Lessons Learned

Systems engineering (SE) tools support the performance of activities and the development of products. SE techniques use tools and methods to complete specific tasks. SE tools and techniques support the Program Manager and Systems Engineer in performing and managing the SE activities and processes to improve productivity and system cost, schedule, capabilities, and adaptability. The program should begin applying SE tools and techniques during the early stages of program definition to improve efficiency and traceability and to provide a technical framework for managing the weapon system development.

Collaboration tools allow the program office and developer to exchange data and analyses easily. Analytical tools and techniques also can assist in the development and validation of system designs. It is critical that the Systems Engineer understand the constraints and limitations of any particular analysis tool or technique, and apply this understanding when making assessments or recommendations based on its output.

Before selecting and implementing a SE tool or technique, the Systems Engineer should consider:

- Needs and constraints of the program (e.g., complexity, size, and funding)
- Applicability to required tasks and desired products
- Computer system requirements, including peripheral equipment
- Licensing and maintenance costs
- Technical data management (see DAG section 4.3.8. Technical Data Management Process)
- Integration with other SE tools in use within the program, by the developer, and by externally interfacing programs
- Cost to train the user to apply the tool or technique
- Number and level of expertise of Government and contractor staff (both users of the tool and users of the tool outputs)
- Feasibility of implementing the tool or technique throughout the acquisition life cycle

Major Defense Acquisition Programs (MDAPs) and Major Automated Information System (MAIS) programs should clearly identify tools in use, define tool interfaces when the Government and developer select different tools to use for the same purpose, and describe how the tools support the program's SE approach. This information is documented in the program's Systems Engineering Plan (SEP) Table 4.7-1 Engineering Tools.

Table 4.3.19.T1 lists general capabilities and features of SE tools and the SE processes they might support.

Table 4.3.19.T1. SE Process-Related Tools

SE Process	Tool Capabilities / Features
Technical Planning	• Assists in planning and scheduling activities • Assists in resource planning, tracking, and allocation • Facilitates cost estimation
Decision Analysis	• Assists in trade-off analysis • Provides optimization and sensitivity analysis capability • Assists in recording, tracking, evaluating, and reporting decision outcomes
Technical Assessment	• Assists in tracking, measuring, and assessing metrics • Assists in metric collection
Requirements Management	• Provides requirements bidirectional traceability capability • Provides requirements flow-down capability • Tracks requirements changes
Risk Management	• Assists in risk identification, analysis, mitigation planning, mitigation plan implementation, and tracking
Configuration Management	• Assists in the identification of configuration items • Assists in baseline/version control of all configuration items • Assists in ensuring configuration baselines and changes are identified, recorded, evaluated, approved, incorporated and verified
Technical Data Management	• Assists in identification of data requirements • Assists in storage, maintenance, control, use, and exchange of data • Assists in document preparation, update, and analysis
Interface Management	• Assists in capturing system internal and external interfaces and their requirement specifications • Assists in assessing compliance of interfaces among system elements of the system or systems of systems • Produces a view of interface connectivity
Stakeholder Requirements Definition	• Assists in capturing and identifying stakeholder requirements • Assists in analyzing and maintaining stakeholder requirements
Requirements Analysis	• Assists in requirements definition and decomposition • Interfaces with architecting tools • Supports Requirements Validation

SE Process	Tool Capabilities / Features
Architecture Design	• Assists in development of functional and physical architectures • Provides traceability among architectural components • Supports multiple views
Implementation	• Assists in development of the system design, prototypes, and alternate solutions • Assists in realization of the system, system elements, and enabling system elements
Integration	• Assists in integration-planning activities • Assists in assembling lower-level system elements into successively higher-level system elements • Provides analysis and simulation capability
Verification	• Assists in determining the system and system elements performance as designed through demonstration, examination, analysis, and test
Validation	• Assists in determining, the effectiveness, suitability and survivability of the system in meeting end-user needs
Transition	• Assists in planning and executing delivery and deploying of the system to the end user for use in operational environment

4.3.19.1. Modeling and Simulation

4.3.19.1. Modeling and Simulation

Models and simulations are SE tools used by multiple functional area disciplines during all life-cycle phases. Modeling is essential to aid in understanding complex systems and system interdependencies, and to communicate among team members and stakeholders. Simulation provides a means to explore concepts, system characteristics, and alternatives; open up the trade space; facilitate informed decisions and assess overall system performance.

Modeling and simulation provide:

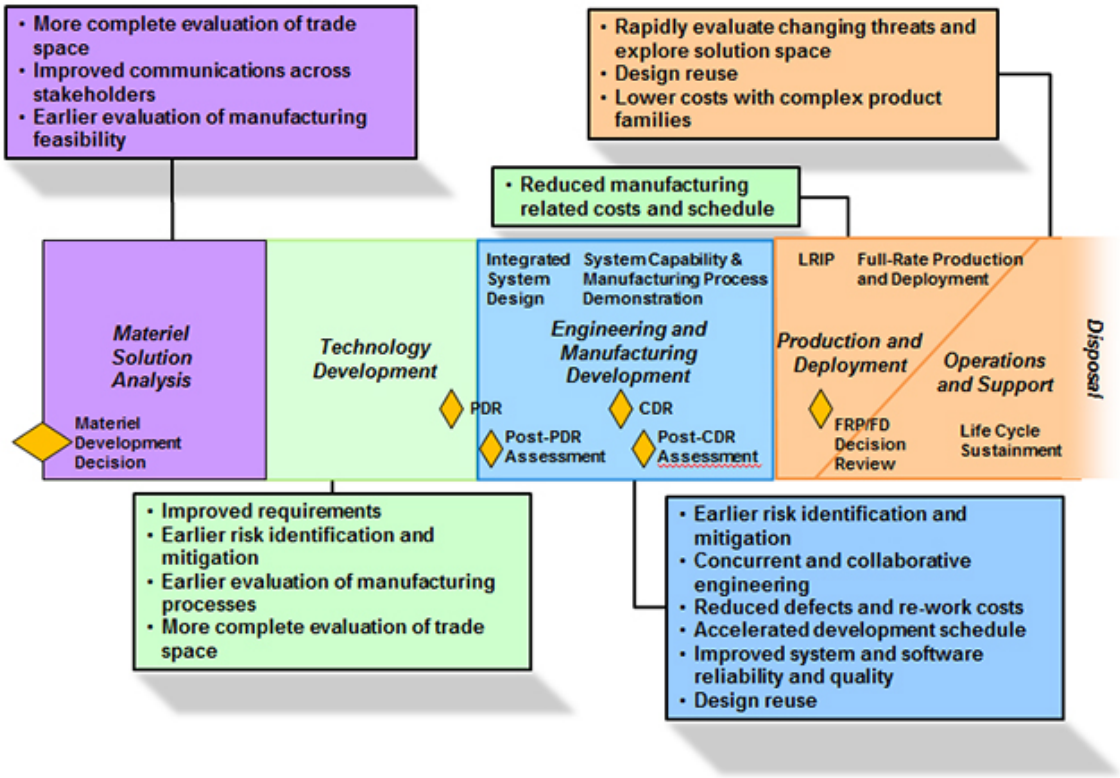
- Insight into program cost, schedule, performance, and supportability risk
- Understanding of capabilities and the requirements set
- Data to inform program and technical decisions
- Efficient communication and shared understanding among stakeholders about relationships between system requirements and the system being developed, through precise engineering artifacts and traceability of designs to requirements
- Better analysis and understanding of system designs (including system elements and enabling system elements), therefore providing a greater understanding of the reasons for defects and failures at all levels

- Greater efficiencies in design and manufacturing by reducing the time and cost of iterative build/test/fix cycles
- Timely understanding of program impacts of proposed changes

The DoD Acquisition Modeling and Simulation Working Group Systems Engineering Modeling, Simulation, and Analysis Fundamentals (located on the DASD(SE) website) recommends that all programs identify and maintain "a collection of related information, representing all necessary viewpoints on the design, and capturing all relevant system interactions." The Program Manager and Systems Engineer should consider directing the use of such a collection when planning for the development, use, and application of models, simulations, and analyses on their program. This collected information can help drive consistency and integration among SE and analytical tools, and provide the program with a capability to assess potential design changes as well as system upgrades throughout the life cycle. Figure 4.3.19.1.F1. shows some benefits of using modeling and simulation throughout the acquisition life cycle. This figure is adapted from a 2010 National Defense Industrial Association (NDIA) Systems Engineering Division "Model-Based Engineering (MBE)" study and is used with permission.

Modeling and simulation should take advantage of opportunities for reuse (see DoD Modeling and Simulation Catalog). Models and simulations developed in early acquisition phases may be repurposed for other activities during later phases (e.g., engineering models can be used in training simulations).

Figure 4.3.19.1.F1. Benefits of Using Modeling and Simulation throughout the Acquisition Life Cycle



SE requires use of models and simulations from many disciplines and across a hierarchy of perspectives that range from an engineering/technical level up to the campaign/strategic level in order to effectively analyze requirements, design, cost, schedule, performance, and risk. These models and simulations often exist, but sometimes need to be newly developed, which can be costly. An option for new development is to consider federating existing models and simulations, using any of various interoperability standards, in order to create needed capability. Program Managers and Systems Engineers should consider how to leverage M&S interoperability as they plan for M&S use throughout a program's life cycle. Modeling and simulation is also used to support developmental test and evaluation (DT&E) and operational test and evaluation (OT&E).

Roles, Responsibilities, and Activities

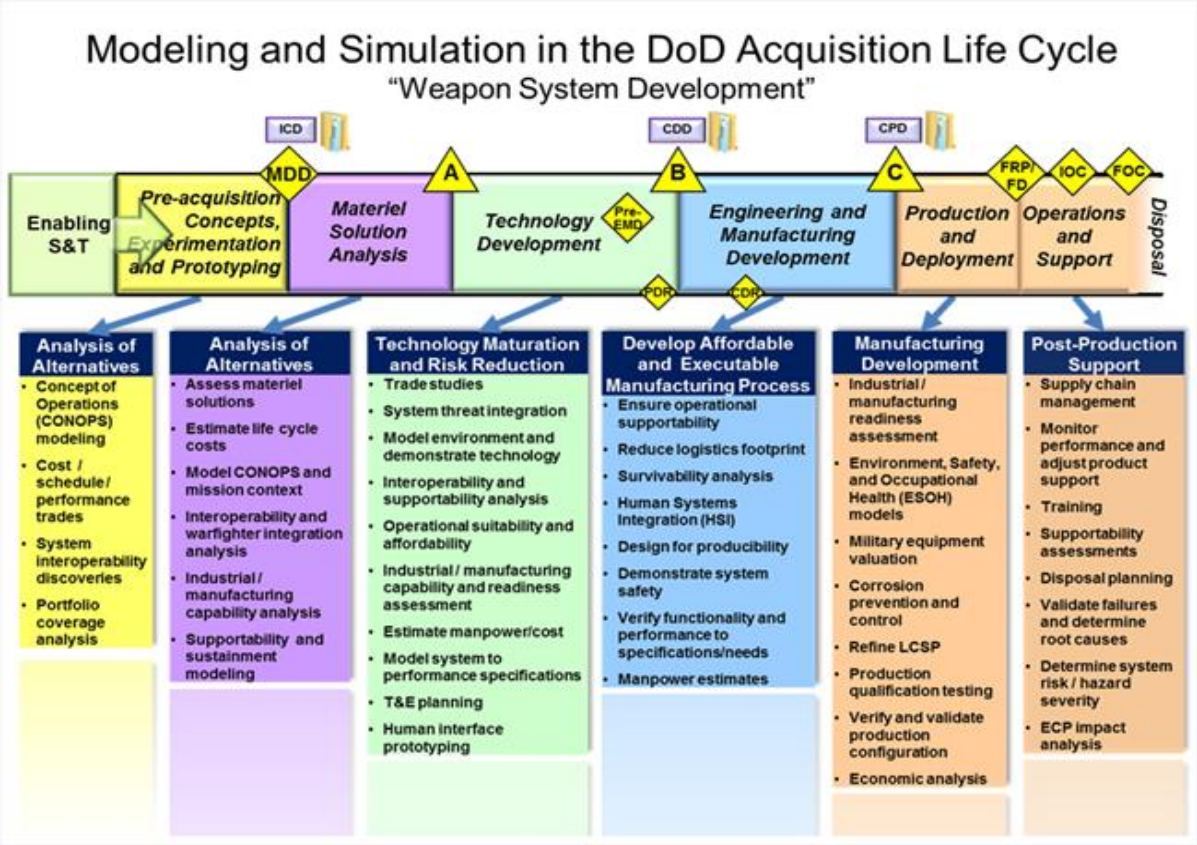
To make effective and appropriate use of modeling and simulation, the Program Manager and Systems Engineer should ensure that planned modeling and simulation activities are:

- Complete and comprehensive, including all efforts anticipated throughout the life cycle, to include planning, development, and acceptance through proper verification, validation, and accreditation (VV&A); (see DAG Chapter 9 Test and Evaluation)
- Reflected in the program's technical planning (Work Breakdown Structure (WBS), schedules, budgets, Systems Engineering Plan (SEP), and other program documentation; see DAG section 4.3.2. Technical Planning Process)
- Appropriately resourced, including a properly skilled workforce

The Program Manager and Systems Engineer should establish and maintain a repository of all relevant modeling and simulation data products that describe what the system is and does. This repository also should contain descriptive system information that could be used to feed other modeling and simulation efforts. They should ensure that all modeling and simulation products are established, maintained, controlled, and resourced to achieve an efficient and effective acquisition program.

Figure 4.3.19.1.F2 shows some applications of modeling, simulation, and analysis throughout the life cycle.

Figure 4.3.19.1.F2. Various Applications of Modeling and Simulation



The Program Manager and Systems Engineer should ensure that the program's modeling and simulation activities are coordinated, managed, and controlled such that products are consistent with the system and architecture design at all levels. Modeling and simulation planning should be part of the overall program plan; and should be integrated with it. The program may choose to integrate the modeling and simulation planning details into the program plan or create a separate modeling and simulation planning document. If the documents are separate, the program must ensure the modeling and simulation planning is kept up to date as the program plan adjusts. Program Managers should follow their local modeling and simulation organizations standards for planning managing and controlling such activities.

Models and simulations should be:

- Developed and matured through the life of the program
- Properly managed and controlled as part of the program's technical baseline
- Developed and documented, to include metadata (see Modeling and Simulation Community of Interest Discovery Metadata Specification (MSC-DMS)) and open systems standards, to maximize opportunity for reuse and repurposing (both within the program and in support of other acquisition efforts)
- Included as part of the technical data package to be transitioned into the next phase of the life cycle or into other efforts

Modeling and modeling artifacts should be evident in the contents of the required program technical reviews and in the baselined technical data needed to support major program reviews and program decisions.

4.3.19.2. Sustainability Analysis

4.3.19.2. Sustainability Analysis

The sustainability analysis, using a Life Cycle Assessment (LCA) method, is a tool to assist the Systems Engineer in designing more sustainable systems - those which use fewer resources over the life cycle, have fewer impacts on human health and the environment, and thus have a lower total ownership cost (TOC). The Program Manager should make sustainability considerations an integral part of both a robust trade space analysis and a comprehensive supportability analysis. These sustainability analyses can help reduce system TOC by uncovering previously hidden or ignored life-cycle costs, leading to more informed decisions earlier in the acquisition life cycle. They can also help make systems more affordable and improve the accuracy of life-cycle cost estimates.

Large military systems and platforms can have a life cycle of 30 years or more. To meet evolving mission needs far into the future, the system design should incorporate long-term sustainability considerations in order to reduce life-cycle costs. Without a full understanding of life-cycle impacts, significant costs may be unintentionally inserted during acquisition and later exposed by the logistics and operational communities.

"Sustainability" differs from "sustainment" in that it relates to the use of resources, and the associated impacts and costs over the system's life cycle. In contrast, sustainment is more concerned with the end user's ability to operate and maintain a system once it is in inventory and deployed. Both aspects need to be addressed in the design process.

Executive Order (E.O.) 13514, "Federal Leadership in Environmental, Energy and Economic Performance" dated October 5, 2009, establishes an integrated Federal Government strategy for sustainability. As required by the E.O., DoD generated a Strategic Sustainability Performance Plan (SSPP) that is updated annually. The SSPP identifies DoD goals for efficiency and reductions in energy, water, solid waste, and use of hazardous chemicals and materials.

A sustainability analysis examines and compares various system attributes associated with energy, water, solid waste, chemicals, materials, and land use. Outputs include decision diagrams (i.e., Kivat/spider-web diagrams) that compare alternatives according to their relative sustainability indicators and related costs. These diagrams can be used to develop system life-cycle cost estimates.

A sustainability analysis can support numerous acquisition activities, including:

- Analysis of Alternatives to compare conceptual alternatives
- Trade space analysis to compare how sustainability attributes (e.g., chemical or material choices, water or solid waste) affect life-cycle cost, TOC, performance, human health,

and the environment
- Business Case Analysis using the LCA method to include sustainability as one of the elements in the analysis
- Preliminary design to select the most sustainable system that meets performance requirements and end-user needs
- Supportability analysis to help ensure the use of resources throughout the life cycle is considered and the system is supportable
- Detailed design to select the most sustainable components

The Streamlined Life Cycle Assessment Process for Sustainability in DoD Acquisitions is specifically for use in the DoD acquisition process. It combines LCA with multi-attribute analysis. It integrates a number of trade space and design considerations and provides a procedure to compare conceptual or detailed design alternatives. The streamlined LCA can be applied in a qualitative mode even when data are lacking, and can be accomplished with minimal resources. It is intended to ensure consideration of important downstream impacts and costs in trade-off and design decisions. The method is consistent, without duplication, with other considerations such as operational energy, supportability, and environment, safety, and occupational health (ESOH).

4.3.19.3. Value Engineering

4.3.19.3. Value Engineering

Value Engineering (VE) is an organized, systematic technique that analyzes the functions of systems, equipment, facilities, services, and supplies to ensure they achieve their essential functions at the lowest life-cycle cost consistent with required performance, reliability, quality, and safety. In today's environment, many systems remain in inventory for a longer time than initially envisioned. Budgetary realities (i.e., affordability) often dictate extending a system's operational life through major modifications or upgrades (e.g., block changes or preplanned product improvements), rather than acquiring a new system. Therefore, opportunities for large VE savings extend well into sustainment.

A VE analysis is a type of process improvement. Key steps include:

- Scoping the issue, improvement targets, and evaluation factors
- Identifying specific areas/functions for evaluation
- Collecting and analyzing data
- Exploring alternative approaches
- Developing and presenting specific recommendations
- Implementing directed changes

By following this process, the Program Manager can analyze the functions of an item or process to determine best value, identify and reduce unnecessary costs, increase productivity, enhance quality, and improve system and program performance. VE supports most aspects of the Better Buying Power initiative:

- Affordability and cost growth: VE critically compares the cost and value of every requirement to focus the program on providing only necessary functions at a minimum overall cost. This represents a systematic approach for attaining return on investment.
- Promote competition: Program Managers can employ VE to identify technical data describing required functions of system elements, enabling multiple suppliers to bid.
- Provide incentives for productivity and innovation: VE provides industry with an incentive to reduce costs; the developer receives a share in the savings if the Government implements a VE change.

Federal Acquisition Regulation (FAR) Parts 48 and 52 mandate inclusion of a VE clause in many Government contracts. This clause allows the developer to receive a share of the cost savings generated from Value Engineering Change Proposals (VECP). (See SD-24 Value Engineering: A Guidebook of Best Practices and Tools for additional details.)

Roles, Responsibilities, and Activities

Program Managers and Systems Engineers should encourage both in-house VE and VECP-based studies and trade-offs on every activity or contract with a value exceeding the simplified acquisition threshold. While a common misconception is that VE applies only to production, successful introduction of VE may occur at any point in the life cycle. The most opportune time to apply VE is early in the life cycle, before production begins, before preparation of field or technical manuals, and before finalizing logistics support plans.

Program Managers and Systems Engineers should consider applying VE principles throughout their program. They should investigate VE saving for:

- Hardware, software, or human components
- Development, production, test, or manufacturing
- Specifications and standards
- Facilities design and construction
- Contract requirements
- Other program documentation

The following examples are potential areas in which the application of VE and VECP may provide a benefit:

- The Analysis of Alternatives and associated cost-effectiveness studies can use VE to evaluate functions and essential requirements, and develop possible alternatives offering improved value
- VE analyses can support the process for transitioning technology from the technology base into program-specific preliminary design efforts; the Program Manager and Systems Engineer can compare the function, cost, and worth of each requirement and the derived specifications
- As part of the development and refinement of the functional and allocated baselines, VE can help:
    - Identify the necessary top-level functions for each of the missions considered

    - Identify technical approaches to the missions
    - Identify necessary lower-level functions for each technical approach
    - Evaluate each function in terms of technical feasibility
    - Estimate the cost of various functions
- VE can contribute to SE activities during production and deployment by devising alternative means for achieving required functions and developing alternative designs to meet functional needs
- VE evaluations can improve manufacturing processes, methods, and materials
- After fielding, VE can examine advances in technology or changes in user requirements to assess potential savings

Additional resources available to the Program Manager and Systems Engineer to learn more about VE as a tool to reduce costs include:

- Defense Acquisition University (DAU) Continuous Learning Module (click on CLE001)
- **DoD VE informatio**n as provided by the Institute for Defense Analyses
- SD-24, Value Engineering: A Guidebook of Best Practices and Tools
- Office of Management and Budget Circular A-131

4.3.19.4. Lessons Learned, Best Practices, Case Studies

4.3.19.4. Lessons Learned, Best Practices, Case Studies

Most programs represent a new combination of existing capabilities or the insertion of incremental advances in technology. By reviewing the successes, failures, problems, and solutions of similar programs, Program Managers and Systems Engineers can gain insights into risks, uncertainties, and opportunities that their programs may encounter.

Lessons learned and case studies generally describe areas of risk, pitfalls encountered in programs, and strategies employed to mitigate or fix problems when they arose. Best practices are proven techniques and strategies that can avoid common problems and improve quality, cost, or both.

Best practices and lessons learned are applicable to all aspects of a program - technical, managerial, and programmatic - and at any point in the acquisition life cycle. However, they are not universal or "one-size-fits-all" solutions. The greatest benefits occur when Program Managers and Systems Engineers judiciously select successful practices or strategies from analogous programs/systems and tailor them to meet current program needs.

Design, build, test, and certification standards are an implementation of lessons learned over time. Program Managers and Systems Engineers should be aware that Standards are not ad hoc requirements developed by a single engineer or program office. They result from years of engineering, manufacturing, or sustainment knowledge that eventually migrates to a standard that should be followed.

Program Managers and Systems Engineers should be aware of available resources, and they

should take advantage of prior experience and knowledge gained when appropriate. Various organizations in DoD, industry, and academia produce and maintain online repositories of lessons learned, best practices, and case studies. These resources can serve as a starting point for Program Managers and Systems Engineers to search for and find relevant data that can be applied to their current program. Knowledge sharing resources include, but are not limited to:

- Service lessons learned repositories (including Service safety centers)
- Government Accountability Office reports
- DoD Systems Engineering community of practice websites
- Other Departments and Agencies such as National Aeronautics and Space Administration (NASA) or Department of Energy (DoE)
- Professional organizations such as the International Council on Systems Engineering (INCOSE) or the Institute of Electrical and Electronics Engineers (IEEE)
- Industry organizations such as National Defense Industrial Association (NDIA) or Aerospace Industries Association (AIA)

Program Managers and Systems Engineers are encouraged to research current analogous programs, not just past programs, that may be experiencing similar challenges and have not yet formally documented what they have learned. The Program Manager and Systems Engineer should ensure that the program establishes and utilizes a robust process to identify and document best practices and lessons learned, to aid both internal activities and other programs. This process should focus on ensuring accurate and timely documentation of all relevant information, and the Systems Engineer should monitor its use and products throughout the life cycle. Each best practice or lesson learned that is developed throughout the program execution should include enough contextual information about the program and surrounding circumstances so that future practitioners find it useful. Program Managers and Systems Engineers should consider using this data as a form of process improvement feedback, or as evidence for proposing policy and guidance changes.